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

Part 3: On-board transmitter simulation

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

Partie 3: Simulation des émetteurs embarqués

Reference number
ISO 11451-3:2007(E)

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Foreword

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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 11451-3 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

This second edition cancels and replaces the first edition (ISO 11451-3:1994), which has been technically revised.

ISO 11451 consists of the following parts, under the general title *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy*:

— *Part 1: General principles and terminology*

— *Part 2: Off-vehicle radiation sources*

— *Part 3: On-board transmitter simulation*

— *Part 4: Bulk current injection (BCI)*

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

Part 3: **On-board transmitter simulation**

1 Scope

This part of ISO 11451 specifies methods for testing the immunity of passenger cars and commercial vehicles to electromagnetic disturbances from on-board transmitters connected to an external antenna and portable transmitters with integral antennas, regardless of the vehicle propulsion system (e.g. spark ignition engine, diesel engine, electric motor).

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11451-1 and the following apply.

3.1
integral antenna
permanent fixed antenna which may be built-in, designed as an indispensable part of the portable transmitting device

4 Test conditions

The applicable frequency range of the test method is 1,8 MHz to 18 GHz.

The user of this part of ISO 11451 shall specify the test severity level or levels over the frequency bands. Typical on-board transmitter characteristics (frequency bands, power level and modulation) are given in Annex A.

NOTE Users of this part of ISO 11451 should be aware that Annex A is for information only and cannot be considered as an exhaustive description of various on-board transmitters available in all countries.

Standard test conditions are given in ISO 11451-1 for the following:

- test temperature;
- supply voltage;
- dwell time;
- test signal quality.

5 Test location

5.1 General

This test would typically be performed in an absorber lined shielded enclosure (ALSE). Where national regulations permit, the test can also be performed at an outdoor test site.

5.2 Absorber lined shielded enclosure (ALSE)

An absorber lined shielded enclosure with the characteristics specified in ISO 11451-2 is adequate for this test.

NOTE At frequencies where absorbers are not effective, the reflections in the chamber can affect the exposure of the vehicle.

5.3 Outdoor test site

Where national regulations permit the use of an outdoor test site, the outdoor test site should have an area with a radius of 20 m free from large metal structures or objects. When performing outdoor test-site tests, care shall be taken to ensure that harmonic suppression regulations are met.

6 Test instrumentation

6.1 General

The following test instrumentation is used:

- signal sources with internal or external modulation capability;
- power amplifier(s);
- power meter (or equivalent measuring instrument) to measure the forward and reverse power;
- field generating devices: antennas;
- field probes (for environmental monitoring).

6.2 Signal sources

6.2.1 Transmitters with antenna outside the vehicle

Signal sources for transmitters with antenna outside the vehicle can be:

- simulated on-board transmitters: use of a signal generator and broadband power amplifier;
- commercial on-board transmitters installed in vehicle capable of generating radio frequency (RF) power in their operational frequency ranges with specific output power.

NOTE When using simulated on-board transmitters, it is advisable to place an RF choke (ferrite or powdered iron toroid, depending on frequency) around the coaxial cable to the antenna, in order to reduce skin currents and more closely simulate a transmitter installed in the vehicle.

6.2.2 Transmitters with antenna inside the vehicle

Signal sources for transmitters with antenna inside the vehicle can be:

— simulated portable transmitters: use of a metallic box with similar dimension to the portable transmitter and amplifier (if needed);

— commercial portable transmitters with integral antennas.

6.3 RF power and field monitoring equipment

An in-line power meter is required when using simulated on-board transmitters for measuring power to the antenna. Both forward power and reverse power shall be measured and recorded.

The appropriate guidelines (national regulation, ICNIRP[1], etc.) shall be followed for the protection of the test personnel.

6.4 Antennas

6.4.1 Transmitters with antenna outside the vehicle

6.4.1.1 Simulated on-board transmitters

When an original equipment manufacturer (OEM) antenna is not installed on the vehicle, the antenna(s) described below shall be used.

— For frequency ranges lower than 30 MHz, loaded antennas shall be used. Loaded antennas employ lumped or distributed reactive components with a radiating element physically shorter than quarter wave at resonance.

— For frequency ranges higher than 30 MHz, e.g. for the very high frequency (VHF) and ultra high frequency (UHF) bands, quarter wave antennas should be given preference over 5/8 wave antennas, since there are higher skin currents created by quarter wave antennas.

All antennas shall be tuned on the vehicle for minimum voltage standing wave ratio (VSWR, typically less than 2:1), unless otherwise specified in the test plan. As a minimum, the VSWR value shall be recorded with the antenna on the vehicle at the lower and upper band edge and at a middle frequency (see Annex B for guidance).

NOTE The resulting VSWR is compatible with the design of the RF source.

When an OEM antenna is actually installed on the vehicle, this antenna shall be used for the test in the appropriate frequency range. In this case, the VSWR shall not be adjusted, but shall be recorded.

6.4.1.2 Commercial on-board transmitters

The vehicle OEM antenna shall be used for the test in the appropriate frequency range. In this case, the VSWR shall not be adjusted.

6.4.2 Transmitters with antenna inside the vehicle

6.4.2.1 Simulated portable transmitter

A passive antenna (e.g. quarter wave antenna with counterpoise, sleeve antenna, patch antenna) shall be used.

All antennas shall be tuned on the vehicle for minimum VSWR (typically less than 2:1), unless otherwise specified in the test plan. The antenna shall be tuned in the laboratory to obtain minimum required VSWR with the counterpoise that is intended to be used with the antenna while testing in the vehicle.

As a minimum, the VSWR value shall be recorded with the antenna in the vehicle at the lower and upper band edge and at a middle frequency (see Annex B for guidance).

NOTE The resulting VSWR is compatible with the design of the RF source.

6.4.2.2 Commercial portable transmitters

When a commercial portable transmitter with integral antenna is used, its antenna shall be used for the test in the appropriate frequency range. In this case, the VSWR shall not be adjusted.

6.5 Stimulation and monitoring of the device under test

If remote stimulation and monitoring are required in the test plan, the vehicle shall be operated by actuators which have a minimum effect on the electromagnetic characteristics, e.g. plastic blocks on the push-buttons, pneumatic actuators with plastic tubes.

Connections to monitoring equipment may be accomplished by using fibre-optics or high resistance leads. Other types of leads may be used, but they 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 vehicle may cause malfunctions of the vehicle. Extreme care shall be taken to avoid such an effect.

7 Test set-up

7.1 Transmitters with antenna outside the vehicle

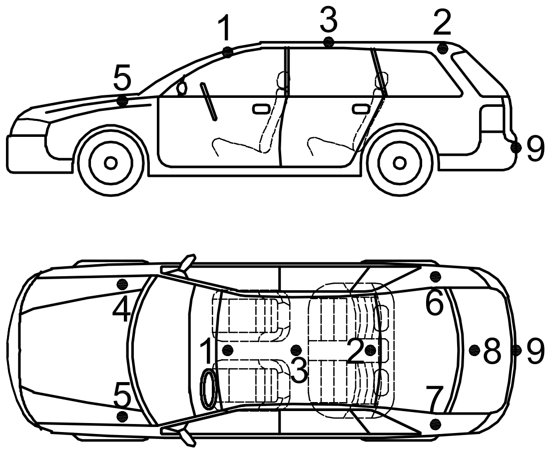
7.1.1 Simulated on-board transmitters

The test can be performed with test antenna(s) or with the vehicle's OEM antenna, as defined in 6.4.1.1.

When a test antenna is used, the location(s) of the transmitting antenna on the vehicle shall be defined in the test plan. If no specific location(s) are agreed between the users of this part of ISO 11451, the following location (s) are recommended, as illustrated in Figure 1:

— locations 1 (vehicle roof, front) and 2 (vehicle roof, rear) are the default locations for frequencies $\geqslant$ 30 MHz;

— location 9 (bumper) is the default location for frequencies $<$ 30 MHz.



Key

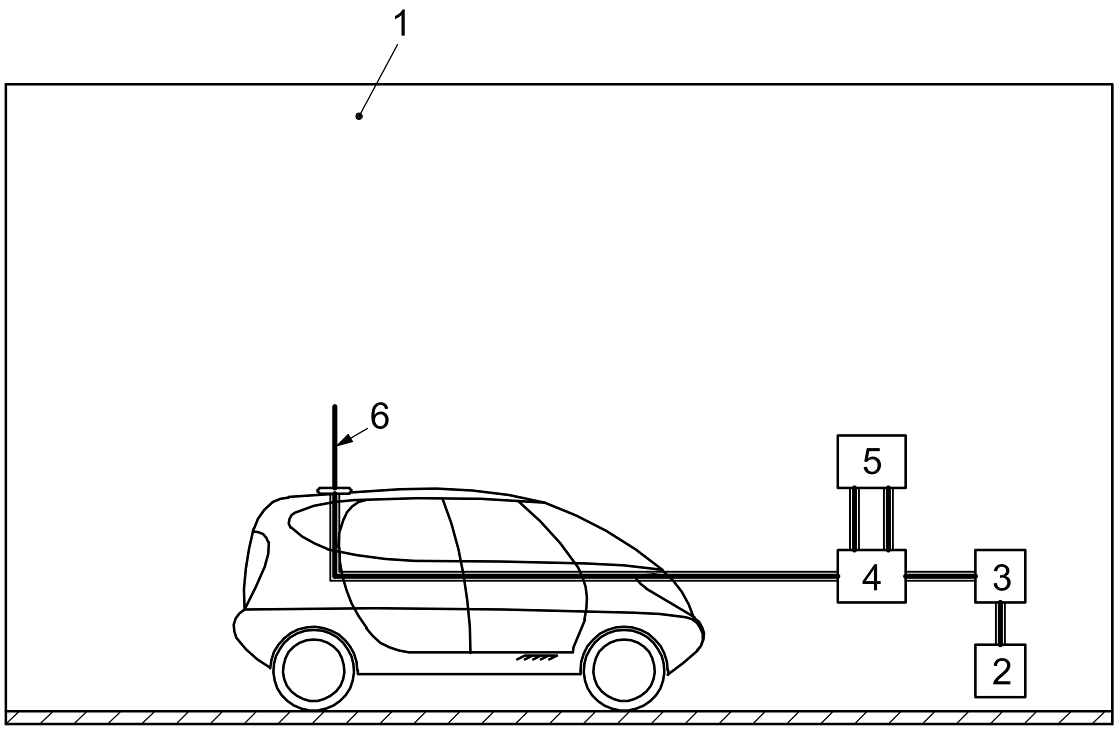
1 vehicle roof (front)
2 vehicle roof (rear)
3 vehicle roof (middle)
4 fender (front, right)
5 fender (front, left)
6 fender (rear, right)
7 fender (rear, left)
8 trunk lid (middle)
9 bumper (middle)

Figure 1 — Recommended locations for antennas outside the vehicle

When the vehicle OEM antenna is used, it should be used as it is installed in the vehicle without any change of antenna characteristics (location, VSWR, etc.).

Examples of test set-up for simulated on-board transmitters are shown in Figure 2 (use of test antenna) and Figure 3 (use of vehicle OEM antenna).

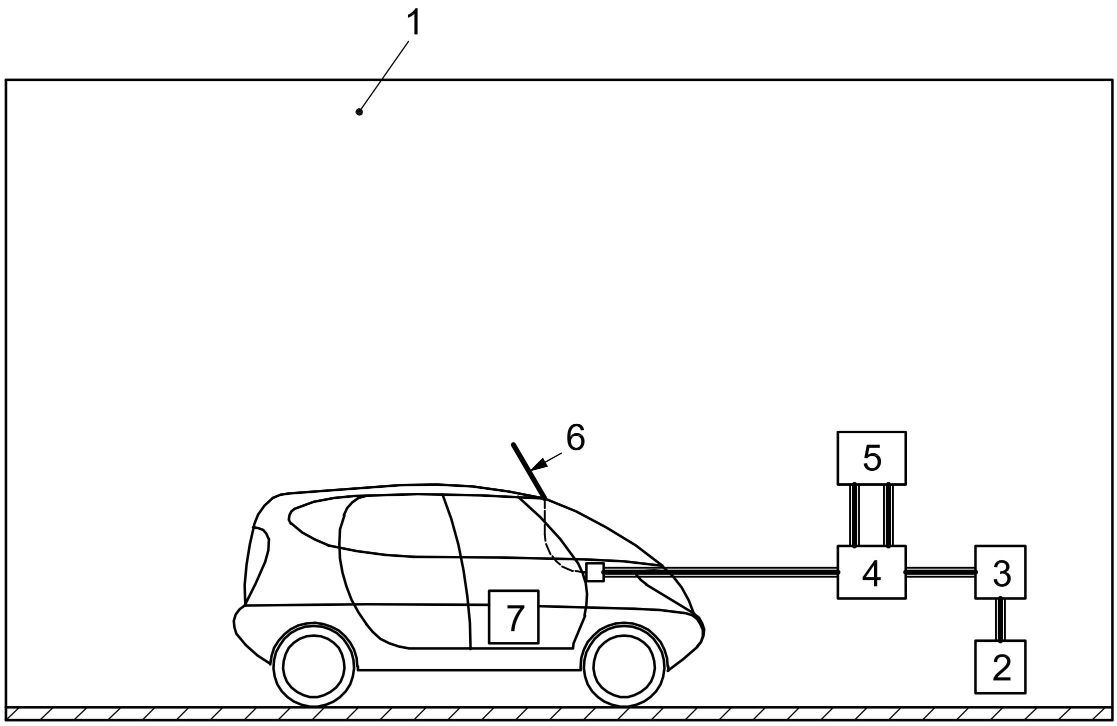
NOTE When the vehicle OEM antenna is used for multiple transmitters/receivers frequency, it is advisable not to use a simulated on-board transmitter (with "broadband" amplifier). The amplifier noise level can be sufficient to degrade some vehicle functions, like GPS satellite reception. The validation of such functions (relative to vehicle on-board-transmitter immunity) can only be performed with the vehicle OEM on-board transmitter. In this case, it may be necessary to operate the on-board vehicle transmitter in real conditions. This can be performed by using specific equipments, like a GSM base station simulator (see 7.1.2 and Figure 4)



Key

1 ALSE
2 RF signal generator (can be outside test facility)
3 power amplifier (can be outside test facility)
4 dual directional coupler (can be outside test facility)
5 power meter (can be outside test facility)
6 test antenna (positions defined in test plan)

Figure 2 — Example of test set-up for simulated on-board transmitter and test antenna



Key

1 ALSE
2 RF signal generator (can be outside test facility)
3 power amplifier (can be outside test facility)
4 dual directional coupler (can be outside test facility)
5 power meter (can be outside test facility)
6 vehicle OEM antenna
7 on-board transmitter (disconnected from vehicle antenna)

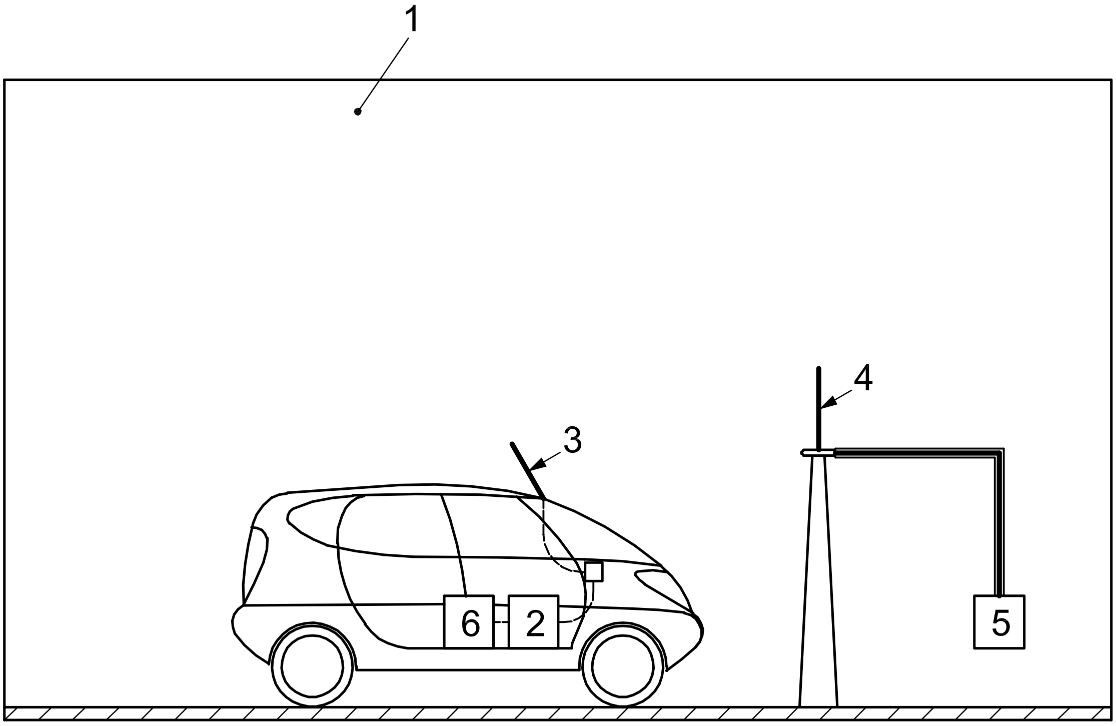
Figure 3 — Example of test set-up for simulated on-board transmitter and vehicle OEM antenna

7.1.2 Commercial on-board transmitters

The vehicle commercial on-board transmitter and OEM antenna should be used as it is installed in the vehicle, without any change of transmitter and antenna characteristics (location, VSWR, etc.).

The modulation signal of the on-board transmitter may be performed with a signal generator connected at the on-board transmitter microphone input (the OEM microphone shall be disconnected).

An example of test set-up for commercial on-board transmitters is shown in Figure 4.



Key

1 ALSE
2 on-board transmitter (connected to vehicle antenna)
3 vehicle OEM antenna
4 antenna (when necessary)
5 base station simulator inside or outside test facility (when necessary)
6 signal generator connected to on-board transmitter microphone input

Figure 4 — Example of test set-up for commercial on-board transmitter

7.2 Transmitters with antenna inside the vehicle

7.2.1 General

The location(s) of a simulated or commercial portable transmitter in the vehicle shall be defined in the test plan. If no specific location(s) are agreed between the users of this part of ISO 11451, the following location(s) are recommended:

— at the driver's head position (centred on the back of the seat at a height of 0,8 m, with the seat in medium position), antenna in vertical polarization;

— at the passenger's head position (centred the back of the seat at a height of 0,8 m, with the seat in medium position), antenna in vertical polarization;

— in specified places where a portable transmitter can be placed, i.e. between front seats, on the vehicle's centre console, storage compartments;

— at the rear passenger's head position (centred on the back of the seat at a height of 0,8 m, with the seat in medium position), antenna in vertical polarization.

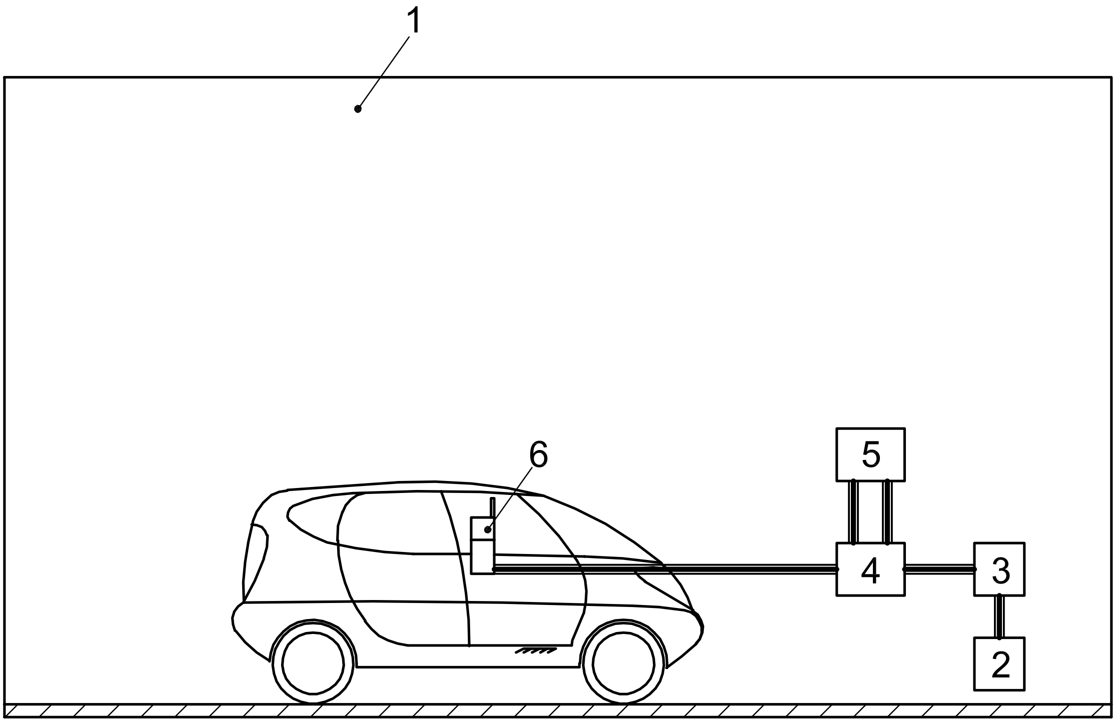
7.2.2 Simulated portable transmitters

An example of test set-up for simulated portable transmitters is shown in Figure 5.

7.2.3 Commercial portable transmitters

Examples of test set-up for commercial portable transmitters are shown in Figures 6 and 7 (use of base station simulator).

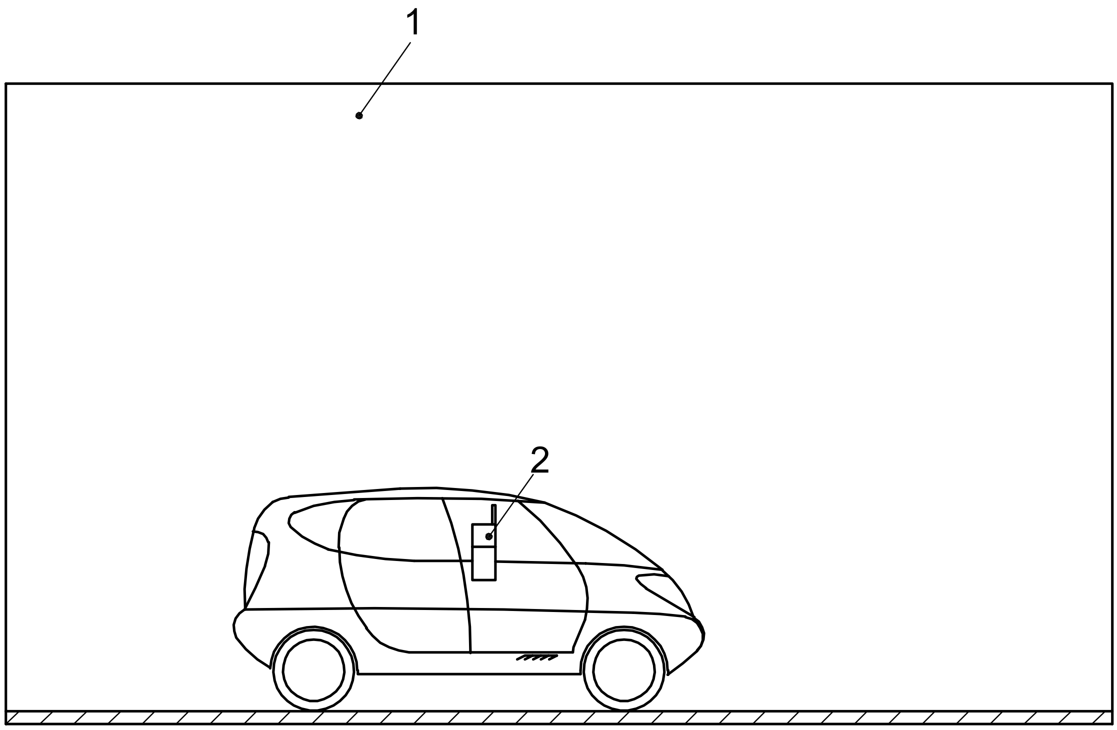
NOTE Certain RF systems (e.g. GSM phones) transmit with different RF power levels and frequencies. In such cases, the test may not necessarily be performed at the maximum RF power level. To control output power and frequency, either devices with modified software or base station simulators can be used.



Key

1 ALSE
2 RF signal generator (can be outside test facility)
3 power amplifier (can be outside test facility)
4 dual directional coupler (can be outside test facility)
5 power meter (can be outside test facility)
6 simulated portable transmitter (positions defined in test plan)

Figure 5 — Example of test set-up for simulated portable transmitters

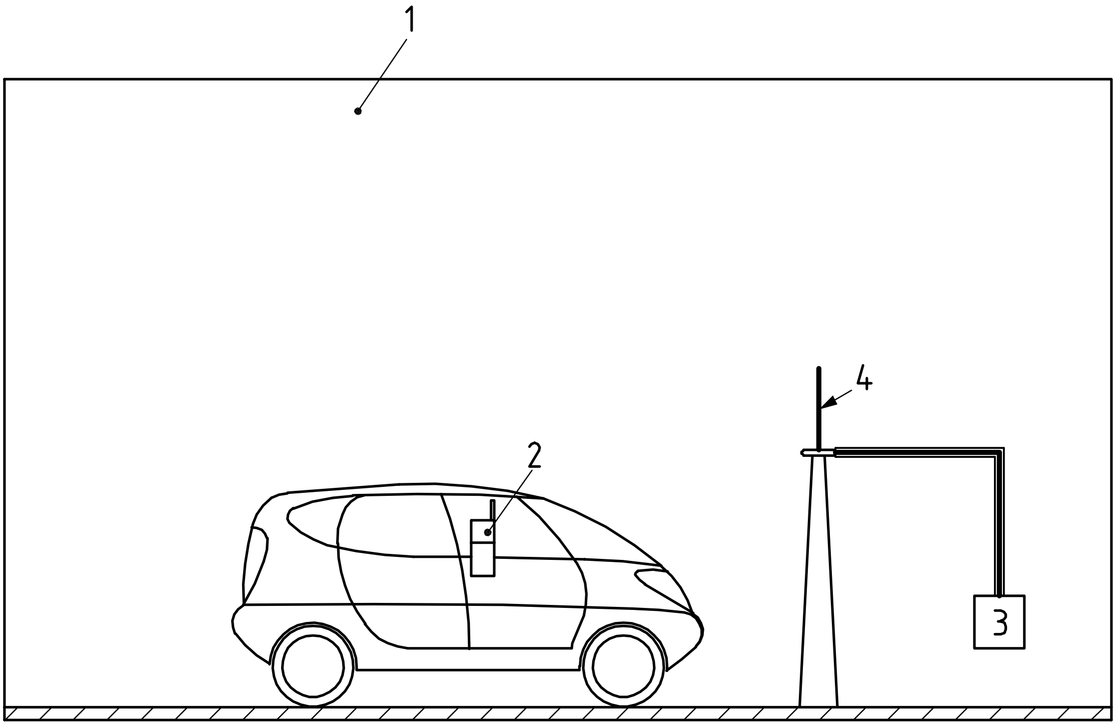


Key

1 ALSE

2 commercial portable transmitter (positions defined in test plan)

Figure 6 — Example of test set-up for commercial portable transmitters



Key

1 ALSE
2 commercial portable transmitter (positions defined in test plan)
3 base station simulator inside or outside test facility
4 antenna (when necessary)

Figure 7 — Example of test set-up for commercial portable transmitters and base station simulator

8 Test procedure

8.1 General

The general arrangement of vehicle, transmitter(s) and associated equipment represents a standardized test condition. Any deviations from the standard test configuration shall be agreed upon prior to testing and recorded in the test report.

The vehicle shall be made to operate under typical loading and operating conditions. These operating conditions shall be clearly defined in the test plan.

8.2 Test plan

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

— test set-up;

— frequency range(s) and associated modulation(s);

— duration of transmission;

— antenna location and polarization;

— routing of the coaxial cable to the antenna in the vehicle (for simulated on-board transmitters);

- vehicle orientation;
- vehicle mode of operation;
- vehicle monitoring conditions;
- vehicle acceptance criteria;
- definition of test severity levels;
- maximum antenna VSWR value if necessary;
- test report content;
- any special instructions and changes from the standard test.

8.3 Test method

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.

8.3.1 Transmitters with antenna outside the vehicle

8.3.1.1 Simulated on-board transmitters

8.3.1.1.1 General

The vehicle, antenna(s) and associated equipment are installed as described in 7.1.1.

The test severity levels are defined in terms of root-mean-square (RMS) power measured for an unmodulated signal [continuous wave (CW)].

8.3.1.1.2 OEM antenna configuration

The reference parameter for the test is the forward power at the vehicle's antenna cable terminal.

For vehicles with an OEM antenna, the test shall at least be performed with this configuration even if tests are also performed with test antenna(s).

With the power amplifier output connected at the OEM antenna cable terminal, increase the forward power level until the predetermined level is achieved. For modulated signals, the peak conservation principle shall be applied as defined in ISO 11451-1. Perform the test at frequencies within the designed bandwidth of the OEM antenna (at least at the lower and upper band edge and at a middle frequency and at frequency steps not greater than those defined in ISO 11451-1).

Continue testing until all frequency bands, modulations, polarizations and antenna locations specified in the test plan are completed.

NOTE At test locations on the vehicle where system interactions are observed (changes/degradations in performance), the test can be repeated in a second step with commercial on-board transmitters transmitting with the maximum allowed power level, as defined in 8.3.1.2.

When required in the test plan, the immunity threshold shall be determined.

8.3.1.1.3 Test antenna configuration

The reference parameter for the test is the net power at the test antenna feed-point.

With the power amplifier output connected at the test antenna feed-point, increase the net power level until the predetermined level is achieved. For modulated signals, the peak conservation principle shall be applied as defined in ISO 11451-1. Perform the test at frequencies within the designed bandwidth of the test antenna (at least at the lower and upper band edge and at a middle frequency and at frequency steps not greater than those defined in ISO 11451-1). The use of more than one test antenna may be necessary to cover an entire frequency band.

Continue testing until all frequency bands, modulations, polarizations and antenna locations specified in the test plan are completed.

NOTE At test locations on the vehicle where system interactions are observed (changes/degradations in performance), the test can be repeated in a second step with commercial on-board transmitters transmitting with the maximum allowed power level, as defined in 8.3.1.2.

When required in the test plan, the immunity threshold shall be determined.

8.3.1.2 Commercial on-board transmitters

The vehicle is installed in the test facility as described in 7.1.2.

The test shall be performed with unmodified commercial on-board transmitter characteristics (power, modulation, etc.) and the unmodified vehicle OEM antenna. Any exception to this practice shall be specified in the test plan.

NOTE In general commercial, the on-board transmitter power considered for this test is the commercially available/declared value of rated power.

Operate the commercial on-board transmitter connected to the OEM antenna in the configuration(s) indicated in the test plan, noting any anomalies.

Continue testing until all on-board transmitter(s) specified in the test plan are completed.

8.3.2 Transmitters with antenna inside the vehicle

8.3.2.1 Simulated portable transmitters

The vehicle, antenna(s) and associated equipment are installed as described in 7.2.2.

The reference parameter for the test is the net power at the simulated portable transmitter feed-point.

The adjustment of the net power level shall be performed with the simulated portable transmitter placed outside the vehicle (at a minimum distance of 1 m from any part of the vehicle and from the test enclosure) until the predetermined level is achieved. Record the forward power level.

The simulated portable transmitter shall then be placed in the vehicle for the test (without any change of the forward power level recorded during the determination of the net power). For modulated signals, the peak conservation principle shall be applied as defined in ISO 11451-1.

Perform the test at frequencies within the designed bandwidth of the test antenna (at least at the lower and upper band edge and at a middle frequency and at frequency steps not greater than those defined in ISO 11451-1).

With the power amplifier output connected to the antenna, perform the test at the discrete frequencies (defined in Annex A) at the power test levels indicated in the test plan, noting any anomalies.

Continue testing until all frequency bands, modulations, polarizations and simulated portable transmitter locations specified in the test plan are completed.

NOTE Because it is not practical to perform the test at every possible location of a portable transmitter inside the vehicle, the test can be performed as a first step for limited defined locations with power levels higher than the typical one given in Annex A.

At test locations on the vehicle where system interactions are observed (changes/degradations in performance), the test can be repeated in a second step with commercial portable transmitters transmitting with the maximum allowed power level, as defined in 8.3.2.2.

8.3.2.2 Commercial portable transmitters

The vehicle and associated equipment are installed as described in 7.2.3.

The test shall be performed with unmodified commercial portable transmitter characteristics (power, modulation, antenna). Any exception to this practice shall be specified in the test plan.

NOTE In general, the commercial portable transmitter power considered for this test is the commercially available/declared value of rated power.

Operate the commercial portable transmitter in the configuration(s) indicated in the test plan, noting any anomalies.

Continue testing until all portable transmitter types and locations specified in the test plan have been tested.

8.4 Test report

As required by the test plan, a test report shall be submitted, detailing information regarding the test equipment, test site, test set-up, systems tested, frequencies, power levels, the antenna used, the portable or commercial transmitter used, VSWR values, system interactions and any other information relevant to the test.

Annex A
(informative)

Typical characteristics of on-board transmitters

Examples of typical characteristics for vehicle on-board transmitters are given in Tables A.1 and A.2, and an explanation of terms used in these tables is given in Table A.3. These characteristics are for information only: frequency bands may be different from one region to another, and the use of power levels greater than those indicated can be expected.

For amplitude modulation (AM) and pulse modulation, powers are specified using the peak conservation principle (RMS power of a CW signal with same peak amplitude).

Table A.1 — Typical characteristics for transmitters with antenna outside vehicle

Transmitter designation	Frequency band MHz	Power W	Typical transmitter modulation	Test Modulation
short wave	1,8 to 30	100 (RMS)	Telegraphy, AM, SSB, FM	AM 1 kHz, 80 %
8 m	30 to 50	120 (RMS)	FM	CW
6 m	50 to 54	120 (RMS)	Telegraphy, AM, SSB, FM	AM 1 kHz, 80 %
4 m	68 to 87,5	120 (RMS)	FM	CW
2 m	142 to 176	120 (RMS)	Telegraphy, AM, SSB, FM	CW
70 cm	410 to 470	120 (RMS)	Telegraphy, AM, SSB, FM	CW
TETRA/TETRAPOL	380 to 390 410 to 420 450 to 460 806 to 825 870 to 876	20 (Peak)	TDMA/ FDMA, Tetra : π/4 DQPSK	PM 18 Hz, 50 % duty cycle
AMPS/GSM850	824 to 849	20 (Peak)	GMSK, PSK, DS	PM 217 Hz, 50 % duty cycle or PM 217 Hz, Ton = 577 µs t = 4 600 µs
GSM 900	876 to 915	20 (Peak) or 8 (Peak)	GMSK	PM 217 Hz, 50 % duty cycle or PM 217 Hz, Ton = 577 µs t = 4 600 µs
23 cm	1 200 to 1 300	25 (RMS.)	Telegraphy, AM, SSB, FM	CW
PCS, GSM1800/1900	1 710 to 1 785 1 850 to 1 910	2 (Peak) or 1 (Peak)	GMSK	PM 217 Hz, 50 % duty cycle or PM 217 Hz, Ton = 577 µs t = 4 600 µs
IMT-2000	1 885 to 2 025	1 (Peak)	QPSK	PM 1 600 Hz, 50 % duty cycle

Table A.2 — Typical characteristics for transmitters with antenna inside vehicle

Transmitter designation	**Frequency band** MHz	**Power** W	**Typical transmitter modulation**	**Test Modulation**
10 m	26 to 30	10 (RMS)	Telegraphy, AM, SSB, FM	AM 1 kHz, 80 %
2 m	146 to 174	10 (RMS)	Telegraphy, AM, SSB, FM	CW
70 cm	410 to 470	10 (RMS)	Telegraphy, AM, SSB, FM	CW
TETRA/TETRAPOL	380 to 390 410 to 420 450 to 460 806 to 825 870 to 876	10 (Peak)	TDMA/ FDMA, Tetra : $\pi/4$ DQPSK	PM 18 Hz, 50 % duty cycle
AMPS/GSM850	824 to 849	10 (Peak)	GMSK, PSK, DS	PM 217 Hz, 50 % duty cycle or PM 217 Hz, Ton = 577 µs t = 4 600 µs
GSM900	876 to 915	16 (Peak) or 2 (Peak)	GMSK	PM 217 Hz, 50 % duty cycle or PM 217 Hz, Ton = 577 µs t = 4 600 µs
PDC	893 to 898 925 to 958 1 429 to 1 453	0,8 (Peak)	TDMA	PM 50 Hz 50% duty cycle
PCS, GSM1800/1900	1 710 to 1 785 1 850 to 1 910	2 (Peak) or 1 (Peak)	GMSK	PM 217 Hz, 50 % duty cycle or PM 217 Hz, Ton = 577 µs t = 4 600 µs
IMT-2000	1 885 to 2 025	1 (Peak)	QPSK	CW and PM 1 600 Hz, 50 % duty cycle
Bluetooth/WLAN	2 400 to 2 500	0,5 (Peak)	QPSK	PM 1 600 Hz, 50 % duty cycle
IEEE 802.11a	5 725 to 5 850	1(Peak)	QPSK	PM 1 600 Hz, 50 % duty cycle

Table A.3 — Explanation of terms

Term (modulation / access system / name)	Definition	Example of use
AM	Amplitude Modulation	Broadcast
AMPS	Advanced Mobile Phone System	—
BT	Bluetooth	—
DECT	Digital Enhanced Cordless Telecommunications	—
DQPSK	Differential Quadrature Phase Shift Keying	Iridium Satellite Telephone
FDMA	Frequency Division Multiplex Access	—
FM	Frequency Modulation	Broadcast
GMSK	Gaussian Minimum Shift Keying	GSM
GSM 850	Global System of Mobile Phones 850 MHz Band	—
GSM 900	Global System of Mobile Phones 900 MHz Band	—
GSM 1800/1900	Global System of Mobile Phones 1800/1900 MHz Band	—
HAM	Term / Name for licensed Amateur Radio	HAM Radio Station
IEEE 802.11a	802.11 refers to a family of specifications developed by the IEEE for wireless LAN technology	WLAN
IMT-2000	International Mobile Telecommunications 2000	UMTS
PCS	Personal Communications Service	—
PDC	Personal Digital Cellular	—
PM	Pulse Modulation	PDC
PSK	Phase Shift Keying	CDMA
QPSK	Quadrature Phase Shift Keying	UMTS, W-LAN
SSB	Single Side Band	Military, HAM Radio
Telegraphy (CW)	Morse telegraphy / Coded Work	—
TDMA	Time Division Multiple Access	Tetra 25, DECT, GSM
TETRA	Terrestrial Trunked Radio	—
TETRAPOL	Terrestrial Trunked Radio Police	—
UMTS	Universal Mobile Telecommunication System	—
WLAN	Wireless Local Area Network	—
10 m/6 m/2 m/70 cm/23 cm	HAM Radio Band as wavelength	—

Annex B
(informative)

Guidance on tuning antennas on the vehicle for minimum voltage standing wave ratio (VSWR)

Where the test level is specified using net power, the required forward power at the coupler can be calculated based on knowledge of cable loss and measurement of VSWR at the coupler.

At the antenna, the ratio of reflected to forward power is related to VSWR as defined in Equation (B.1), and the ratio of net to forward power is related to VSWR as defined in Equation (B.2):

$$\frac{P_{\text{ant,REFL}}}{P_{\text{ant,FWD}}} = \left(\frac{k_{\text{VSWR,ant}}-1}{k_{\text{VSWR,ant}}+1}\right)^2 \tag{B.1}$$

$$\frac{P_{\text{ant,NET}}}{P_{\text{ant,FWD}}} = 1-\left(\frac{k_{\text{VSWR,ant}}-1}{k_{\text{VSWR,ant}}+1}\right)^2 \tag{B.2}$$

$$\Delta P = 10 \times \lg\left(\frac{P_{\text{ant,NET}}}{P_{\text{ant,FWD}}}\right) \tag{B.3}$$

where

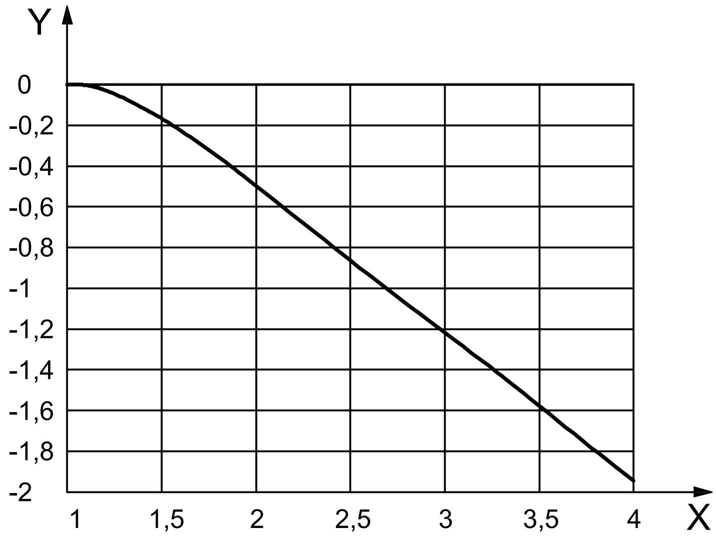
$k_{\text{VSWR,ant}}$ is the voltage standing wave ratio at the antenna;

$P_{\text{ant,REFL}}$ is the reflected power at the antenna;

$P_{\text{ant,FWD}}$ is the forward power at the antenna;

$P_{\text{ant,NET}}$ is the net power at the antenna.

For a cable (transmission line) with 0 dB attenuation, ΔP as a function of VSWR is plotted in Figure B.1.



Key

X voltage standing wave ratio

Y ΔP (dB)

Figure B.1 — Relationship between ΔP and VSWR

The relationship between forward power at the coupler and net power at the antenna can be calculated. If the cable loss between power coupler and antenna is given by A, as defined in Equation (B.4):

$$A = \frac{P_{\text{ant,FWD}}}{P_{\text{meas,FWD}}} \tag{B.4}$$

the net power to the antenna, $P_{\text{ant,NET}}$, as defined in Equation (B.5), is:

$$P_{\text{ant,NET}} = \left(A \times P_{\text{meas,FWD}}\right) - \left(\frac{1}{A} \times P_{\text{meas,REFL}}\right) \tag{B.5}$$

where

$P_{\text{meas,FWD}}$ is the measured forward power;

$P_{\text{meas,REFL}}$ is the measured reflected power.

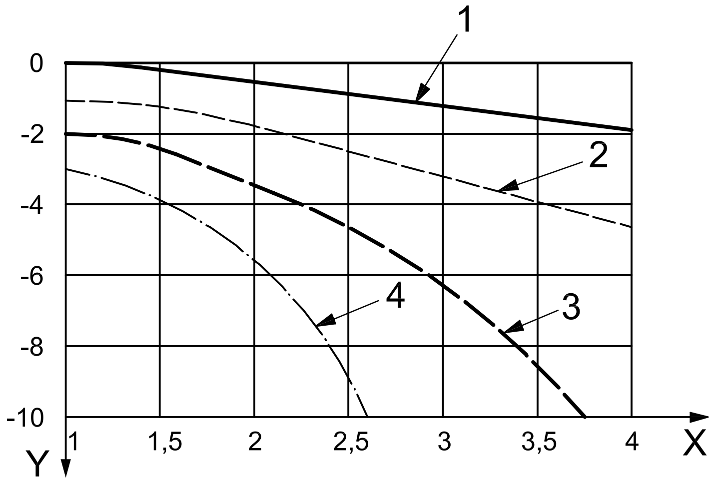
This can be expressed in terms of VSWR measured at the coupler, as defined in Equation (B.6):

$$\frac{P_{\text{ant,NET}}}{P_{\text{meas,FWD}}} = A - \frac{1}{A} \times \left(\frac{k_{\text{VSWR,meas}} - 1}{k_{\text{VSWR,meas}} + 1}\right)^2 \tag{B.6}$$

$$\Delta P' = 10 \times \lg\left(\frac{P_{\text{ant,NET}}}{P_{\text{meas,FWD}}}\right) \tag{B.7}$$

where $k_{\text{VSWR,meas}}$ is the measured voltage standing wave ratio.

The equation results for cable loss values of 0 dB, 1 dB, 2 dB and 3 dB are shown in Figure B.2.



Key

X voltage standing wave ratio

Y $\Delta P'$ (dB)

1 A = 0 dB

2 A = 1 dB

3 A = 2 dB

4 A = 3 dB

Figure B.2 — Relationship between $\Delta P'$ and VSWR

If VSWR and cable loss are low, then antenna net power can be approximated by measured forward power, multiplied by the cable attenuation factor, as defined in Equation (B.8):

$$P_{\text{ant,NET}} = A \times P_{\text{meas,FWD}} \tag{B.8}$$

However, for high VSWR or cable loss, the nonlinear interactions described above shall be taken into consideration to determine the net power delivered to the antenna.

Bibliography

[1] Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz). *Health Physics* 74 (4): 494-522; 1998

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