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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

Reference number
ISO 11452-1:2005(E)

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Foreword

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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.

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ISO 11452-1 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 11452-1:2001), 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*

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

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. ISO 11452 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, transverse electromagnetic (TEM) cell and parallel plate 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.

ISO 11452 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), while Annex B explains the principle of constant peak test level. 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 a part of total vehicle validation as described in ISO 11451, which covers vehicle test methods. It is important to know the correlation between component and vehicle tests.

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 (0,01 MHz to 18 000 MHz) is allowed for the immunity testing of the components in this and the other parts of ISO 11452.

2 Terms and definitions

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

2.1
absorber-lined shielded enclosure
shielded enclosure/screened room with radio frequency-absorbing material on its internal ceiling and walls

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

2.2
amplitude modulation
AM
process by which the amplitude of a carrier wave is varied following a specified law, resulting in an AM signal

2.3
artificial network
AN
network inserted in the supply leads of the DUT which provides, in a given frequency range, a specified load impedance for the measurement of disturbance voltages, and which isolates the DUT from the power supply in that frequency range

2.4
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

2.5
bulk current
total amount of common mode current in a harness

2.6
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

2.7
coupling
means or device for transferring power between systems

NOTE Adapted from IEC 60050-726.

2.8
current injection probe
device for injecting current in a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits

2.9
current (measuring) probe
device for measuring the current in a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits

[IEC 60050-161]

2.10
degradation (of performance)
undesired departure in the operational performance of any device, equipment or system from its intended performance

NOTE The term "degradation" can apply to temporary or permanent failure.

[IEC 60050-161]

2.11
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

NOTE Adapted from IEC 60050-726.

2.12
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

[IEC 60050-161]

2.13
electromagnetic disturbance
any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter

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

[IEC 60050-161]

2.14
electromagnetic interference
EMI
degradation of the performance of equipment, transmission channel or system caused by electromagnetic disturbance

NOTE The English words "interference" and "disturbance" are often used indiscriminately.

[IEC 60050-161]

2.15
forward power
power supplied by the output of an amplifier or generator

2.16
functional status
performance level agreed between the customer and the supplier which is specified in the test plan

2.17
ground (reference) plane
flat conductive surface whose potential is used as a common reference

[IEC 60050-161]

2.18
immunity (to a disturbance)
ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[IEC 60050-161]

2.19
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

[IEC 60050-161]

2.20
narrowband emission
emission which has a bandwidth less than that of a particular measuring apparatus or receiver

[IEC 60050-161]

2.21
net power
forward power minus reflected power

2.22
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

NOTE 1 When this direction varies with time, the property may be characterized by the locus described by the extremity of the considered field vector.

NOTE 2 Adapted from IEC 60050-726.

2.23
pulse modulation
PM
process by which the amplitude of a carrier wave is varied following a specified law, resulting in a PM signal

2.24
electromagnetic radiation
phenomenon by which energy in the form of electromagnetic waves emanates from a source into space

NOTE By extension, the term “electromagnetic radiation” sometimes also covers induction phenomena.

[IEC 60050-161]

2.25
electromagnetic radiation
energy transferred through space in the form of electromagnetic waves

[IEC 60050-161]

2.26
reflected power
power reflected by the load due to impedance mismatch between RF source and the load

2.27
shielded enclosure
screened room
mesh or sheet metallic housing designed expressly for the purpose of separating electromagnetically the internal and external environment

[IEC 60050-161]

2.28
standing wave ratio
SWR
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 SWR is expressed by the equation:

$$\mathrm{SWR} = \frac{(1+r)}{(1-r)}$$

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

NOTE 2 Adapted from IEC 60050-726.

2.29
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

[IEC 60050-161]

2.30
(electromagnetic) susceptibility
inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

NOTE Susceptibility is the lack of immunity.

[IEC 60050-161]

2.31
transmission line system
TLS
field-generating device that works in a similar way to a TEM (transverse electromagnetic mode) wave generator

EXAMPLE Stripline, TEM cell, parallel plate.

2.32
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

[IEC 60050-161]

2.33
transverse electromagnetic mode
TEM mode
mode in which the longitudinal components of both the electric and magnetic field strength vectors are everywhere zero

NOTE Adapted from IEC 60050-726.

3 General aim and practical use

The test methods, procedures, test instrumentation and levels specified in ISO 11452 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 11452-7 are presented in Table 1.

Table 1 — Main characteristics of test methods in ISO 11452

Part of ISO 11452 Subject	Applicable frequency range MHz	Coupling to	Test severity parameter and unit	Provisions
ISO 11452-2 Absorber-lined shielded enclosure	80 to 18 000	DUT and wiring harness	Electric field (V/m)	Absorber lined shielded enclosure required
ISO 11452-3 TEM cell	0,01 to 200	DUT and wiring harness or DUT	Electric field (V/m)	DUT and/or wiring harness size limitation
ISO 11452-4 Bulk current injection	1 to 400	Wiring harness	Current (mA)	Shielded enclosure required
ISO 11452-5 Stripline	0,01 to 400	Wiring harness and/or DUT	Electric field (V/m)	Shielded enclosure recommended: DUT size limitation
ISO 11452-7 Direct RF power injection	0,25 to 400	Wiring harness	Power (W)	Influence of isolator on DUT sensor signals

4 General test conditions

4.1 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;
- ± 1 dB for power meter;
- ± 3 dB for field probe.

4.2 Test temperature

The ambient temperature during the test shall be (23 ± 5) °C. If another value is agreed by users of ISO 11452, the value shall be recorded in the test report.

4.3 Supply voltage

The supply voltage during the test shall be (13,5 ± 0,5) V for 12 V electrical systems and (27 ± 1) V for 24 V electrical systems. If other values are agreed by the users of ISO 11452, the values shall be recorded in the test report.

4.4 Modulation

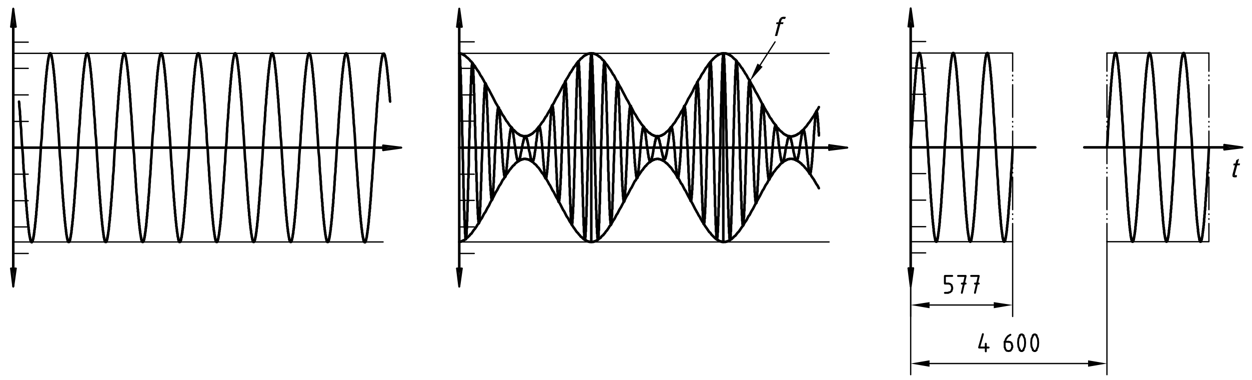
The characteristics of the DUT determine the type and frequency of modulation to be used. If no values or specific modulation techniques are agreed between the users of ISO 11452, the following modulations shall be used.

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 B and Figure 1 b).

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

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 signal**

Key

f frequency: 1 kHz

t time, µs

Figure 1 — Modulation

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

CW: 0,01 MHz to 18 GHz

AM: 0,01 MHz to 800 MHz

PM: 800 MHz to 18 GHz.

4.5 Dwell time

At each frequency, the DUT shall be exposed to the test level for the minimum response time needed to control it. In all cases, this exposure time shall be no less than 1 s.

4.6 Frequency step sizes

All tests in ISO 11452 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 MHz	**Linear steps** MHz	**Logarithmic steps** %
0,01 to 0,1	0,01	10
> 0,1 to 1	0,1	10
> 1 to 10	1	10
> 10 to 200	5	5
> 200 to 400	10	5
> 400 to 1 000	20	2
> 1 000 to 18 000	40	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 maximum susceptibility thresholds.

4.7 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 ISO 11452 (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 this principle (see Annex B).

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

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 ($0 \leqslant m \leqslant 1$).

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.

4.8 Disturbance application

For disturbance application, see 6.4.

5 Instrumentation

5.1 Artificial loads

For module testing, it is desirable that the module be connected to the sensors and loads used in its production application.

Where certain loads and sensors are not convenient to use, it is acceptable to use an electrically equivalent load, provided the artificial loads have the same impedance characteristics as the actual devices over the frequency band under test.

EXAMPLE A motor can be replaced with a network of two resistors, an inductor and a capacitor.

5.2 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.

When required by an individual test method, the DUT, ANs[1)] and terminating loads

— shall be placed on a ground plane,

— shall be bonded to the ground plane as in the intended installation, and

— shall not be otherwise grounded, unless required by the DUT installation instructions.

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

5.3 Power supply

The power supply shall have an internal resistance, R_s, of $< 0{,}01\ \Omega$ d.c. 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.

1) The term *artificial network*, or AN, is applicable to this and all other parts of ISO 11452 excepting ISO 11452-7, where *broadband artificial network* (BAN) is used instead.

5.4 Test signal quality

In the frequency range limited by the bandwidth of both the amplifier and the antenna (transducer) in use, the amplifier output harmonics content (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 is to be verified only during calibration testing.

6 Test procedure

6.1 Test plan

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

- 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, and
- any special instructions and changes from the standard test.

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

6.2 Test methods

6.2.1 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.

6.2.2 Substitution

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.

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

During calibration and testing, both forward and reflected power shall be recorded.

The forward power, P_{for}, required to provide a specific test signal relative to a calibration level can be obtained from the following formula:

$$P_{\text{for}} = P_{\text{for cal}} \left(\frac{L_{\text{tss}}}{L_{\text{cal}}} \right)^k$$

where

$P_{\text{for cal}}$ is the forward power by calibration;

L_{tss} is the test signal severity level;

L_{cal} is the calibration level;

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

6.2.3 Closed loop levelling

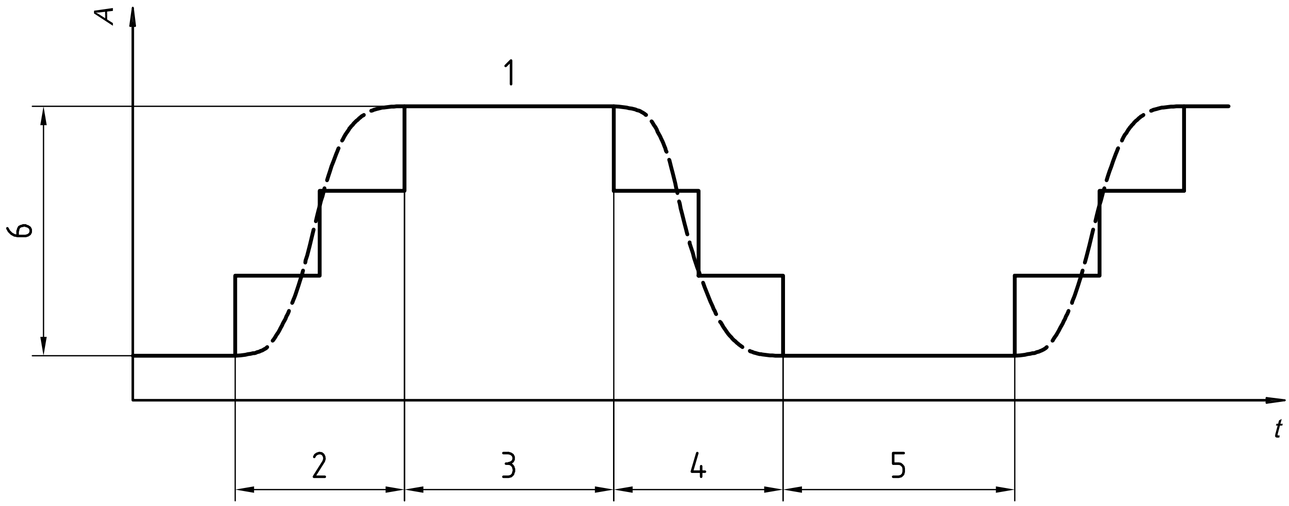
During actual testing with the DUT, the test level (electric field, voltage, current or power) is measured using a calibrated device and fed back to the signal generator in order to either increase or decrease the test level until the predetermined level is achieved.

6.3 Calibration

Calibration shall be performed in accordance with the requirements of each individual test method. The test level versus frequency data shall be established using an unmodulated sine wave signal. The method and results for each calibration shall also be documented in the test report.

6.4 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

A amplitude

t time

1 specified signal level

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

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:

— analog 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.)

6.5 Test report

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

Annex A
(normative)

Functional performance status classification (FPSC)

A.1 General

This annex specifies a general method for the function performance status classification (FPSC) of the functions of automotive electronic devices when using the test methods and under the test conditions given throughout ISO 11452. The appropriate test signals and methods, functional status classification and test signal severity levels are specified in the individual parts of ISO 11452.

It must be emphasized that components or systems shall only be tested under those conditions, as specified in the appropriate parts of ISO 11452, which represent the simulated automotive electromagnetic environments to which the devices would be subjected were they in actual use. 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 serve as a product specification and cannot function as one. It should be used in conjunction with a test procedure specified in the relevant part of ISO 11452. Therefore, no specific values for the test signal severity level are included, since they are to be determined by the vehicle manufacturer and component supplier. Nevertheless, by conforming to this annex, and by careful application and agreement between manufacturer and supplier, the functional status requirements for a specific device can be determined. This annex can, in fact, serve as a statement of how a particular device could be expected to perform under the influence of the specified test signals.

A.2 Essential elements of FPSC

A.2.1 General

Three elements are required to determine an FPSC (see A.2.2 to A.2.4). These may be applied to all electromagnetic disturbance immunity test procedures given in ISO 11452.

A.2.2 Test signal and method

This element provides the reference to respective test signals applied to the device under test for the chosen test method. It usually refers to a specific test procedure, i.e. to the appropriate part of ISO 11452.

A.2.3 Functional status classification

This element describes the operational status of a device during and after exposure to an electromagnetic environment.

— **Class A:** all functions of a device or system perform as designed during and after exposure to a disturbance.

— **Class B:** all functions of a device or system perform as designed during exposure; however, one or more of them may go beyond the specified tolerance. All functions return automatically to within normal limits after exposure is removed. Memory functions shall remain class A.

— **Class C:** one or more functions of a device or system do not perform as designed during exposure but return automatically to normal operation after exposure is removed.

— **Class D:** one or more functions of a device or system do not perform as designed during exposure and do not return to normal operation until exposure is removed and the device or system is reset by a simple "operator/use" action.

— **Class E:** one or more functions of a device or system do not perform as designed during and after exposure and cannot be returned to proper operation without repairing or replacing the device or system.

A.2.4 Test severity level

This element contains the specification of the severity level of essential test parameters. The test signal severity level is the test level (field strength, voltage, current or power) applied to the device under test for a given test method. The device under test shall perform according to its classification of functional status during and after the test. Typical severity level selection tables are included in annexes to the parts of ISO 11452. If the values listed in an annex are determined to be inappropriate, a new value shall be agreed between vehicle manufacturer and component supplier, and shall be recorded in the test report.

A.3 Illustration of FPSC

Tables in an annex to each of the other parts of ISO 11452 give the suggested test levels and the frequency bands, as per Tables A.1 and A.2.

Table A.1 — Suggested test severity levels — Scheme of presentation

Test severity level	**Value** (e.g. V/m, mA, W)
I	.
II	..
III	...
IV	....
V	Specific value agreed between the users of this part of ISO 11452 if necessary.

Table A.2 — Frequency bands

Frequency band	**Frequency range** MHz
F1	⩾ . to ⩽ ..
F2	> .. to ⩽ ...
F3	> ... to ⩽ ....
F4	> .... to ⩽ .....
F5	> ..... to ⩽ ......

Table A.3 is an example of test severity level according to functional status classification.

Table A.3 — Test severity level according to functional status classification

Frequency Band	Test severity level				
	A	B	C	D	E
F1	I		II		
F2		II	III		IV
F3					V
F4		I			
..					
..					

Annex B
(informative)

Constant peak test level

B.1 General

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

B.2 Unmodulated signal

The electric field strength of an unmodulated sine wave signal, E_{CW}, can be written as:

$$E_{CW} = E\cos(\omega t)$$

where

E is the peak value of E_{CW};

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

t is time.

The mean power for the unmodulated signal, P_{CW}, is calculated using

$$P_{CW} = kE^2$$

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

B.3 Modulated signal

The electric field strength energy of an amplitude-modulated signal, E_{AM}, can be written in the form:

$$E_{AM} = E'\left(1 + m\cos(\theta t)\right)\cos(\omega t)$$

where

E'	is the peak amplitude of the unmodulated signal;
$E'(1+m) = E_{AMpeak}$	is the peak value of the modulated signal;
m	is the modulation index ($0 \leqslant m \leqslant 1$);
θ	is the frequency of the modulating signal (i.e. voice, baseband, 1 kHz sine wave);
ω	is the 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, kE'^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

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

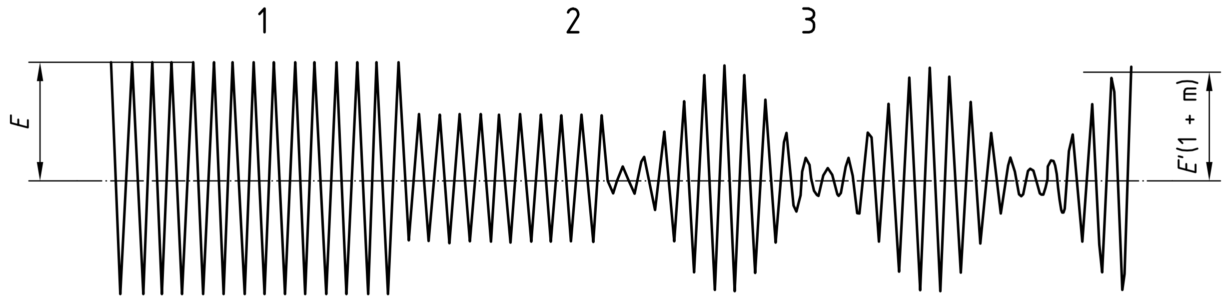
B.4 Peak conservation

B.4.1 General

For peak test level conservation, the peak amplitudes of the unmodulated and amplitude-modulated signals are defined to be identical:

$$E_{CWpeak} = E_{AMpeak}$$

See Figure B.1.



Key

1 CW signal

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

3 AM signal

Figure B.1 — Peak conservation

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

B.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}, is then:

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

Therefore:

$$P_{\mathrm{AM}} = P_{\mathrm{CW}} \frac{2+m^2}{2\,(1+m)^2}$$

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

$$P_{\mathrm{AM}} = 0{,}407\ P_{\mathrm{CW}}$$

B.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_{CWpm}, is then:

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

Therefore:

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

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

$$P_{\mathrm{CWpm}} = 0{,}309 P_{\mathrm{CW}}$$

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