BS ISO 11451-1:2015

BSI Standards Publication

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

Part 1: General principles and terminology

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National foreword

This British Standard is the UK implementation of ISO 11451-1:2015. It supersedes BS ISO 11451-1:2005+A1:2008 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AUE/16, Data Communication (Road Vehicles).

A list of organizations represented on this committee can be obtained on request to its secretary.

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

Part 1: General principles and terminology

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

Partie 1: Principes généraux et terminologie

Reference number
ISO 11451-1:2015(E)

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Foreword

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

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

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

This fourth edition cancels and replaces the third edition (ISO 11451-1:2005), which has been technically revised. It also incorporates the Amendment ISO 11451-1:2005/Amd 1:2008.

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)*

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 the 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 and 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 a vehicle to radiated disturbances have to be established. ISO 11451 provides various test methods for the evaluation of vehicle immunity characteristics (not all methods need be used to test a vehicle).

ISO 11451 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 specifies a general method for function performance status classification (FPSC), Annex B specifies Artificial Networks (AN), Artificial Mains Networks (AMN) and Asymmetric Artificial Networks (AAN), while annex C explains the principle of constant peak test level. Typical severity levels are included in an annex of each of the other parts of ISO 11451.

Protection from potential disturbances needs to be considered in a total system validation, and this can be achieved using the various parts of ISO 11451.

NOTE Immunity measurements of complete 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. ISO 11452 specifies test methods for the analysis of component immunity, which are better suited for supplier use.

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

Part 1:
General principles and terminology

1 Scope

This part of ISO 11451 specifies general conditions, defines terms, gives practical guidelines, and establishes the basic principles of the vehicle tests used in the other parts of ISO 11451, for determining the immunity 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 in this and the other parts of ISO 11451.

2 Normative references

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

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

3 Terms and definitions

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

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

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

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

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

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

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

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

Note 1 to entry: This network is inserted in the DC power lines of the vehicle in charging mode and provides, in a given frequency range, a specified load impedance and which isolates the vehicle from the DC power supply in that frequency range.

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

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

3.6
bonded (ground connection and DC resistance)
grounding connection where the purpose of the bonding is to provide the lowest possible impedance (resistance and inductance) connection between two metallic parts with a d.c. resistance which shall not exceed 2,5 mΩ

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

3.7
bulk current
total amount of common mode current in a harness

3.8
compression point
input signal level at which the measurement system becomes non-linear

Note 1 to entry: When the measurement system is non-linear, the output value will deviate from the value given by an ideal linear system.

3.9
coupling
means or device for transferring power between systems

[SOURCE: IEC 60050-726]

3.10
current injection probe
device for injecting current in a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits

3.11
current (measuring) probe
device for measuring the current in a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits

[SOURCE: IEC 60050-161]

3.12
degradation (of performance)
undesired departure in the operational performance of any device, equipment, or system from its intended performance

Note 1 to entry: The term "degradation" can apply to temporary or permanent failure.

[SOURCE: IEC 60050-161]

3.13
dual directional coupler
four-port device consisting of two transmission lines coupled together in such a manner that a single travelling wave in any one transmission line will induce a single travelling wave in the other, the direction of propagation of the latter wave being dependent upon that of the former

[SOURCE: IEC 60050-726]

3.14
electromagnetic compatibility
EMC
ability of equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbance to anything in that environment

[SOURCE: IEC 60050-161]

3.15
electromagnetic disturbance
any electromagnetic phenomenon which can degrade the performance of a device, equipment, or system or adversely affect living or inert matter

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

[SOURCE: IEC 60050-161]

3.16
electromagnetic interference
EMI
degradation of the performance of equipment, transmission channel, or system caused by electromagnetic disturbance

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

[SOURCE: IEC 60050-161]

3.17
(electromagnetic) susceptibility
inability of a device, equipment, or system to perform without degradation in the presence of an electromagnetic disturbance

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

[SOURCE: IEC 60050-161]

3.18
forward power
power supplied by the output of an amplifier or generator

3.19
ground (reference) plane
flat conductive surface whose potential is used as a common reference

[SOURCE: IEC 60050-161]

3.20
immunity (to a disturbance)
ability of a device, equipment, or system to perform without degradation in the presence of an electromagnetic disturbance

[SOURCE: IEC 60050-161]

3.21
immunity level
maximum level of a given electromagnetic disturbance incident on a particular device, equipment, or system for which it remains capable of operating at a required degree of performance

[SOURCE: IEC 60050-161]

3.22
narrowband emission
emission which has a bandwidth less than that of a particular measuring apparatus or receiver

[SOURCE: IEC 60050-161]

3.23
polarization (of wave or field vector)
property of sinusoidal electromagnetic wave or field vector defined at a fixed point in space by the direction of the electric field strength vector or of any specified field vector, when this direction varies with time

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

[SOURCE: IEC 60050-726]

3.24
portable transmitter
hand-held radio frequency communication device

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

3.25
power mains
general purpose alternating current (AC) or direct current (DC) electric power supply

3.26
pulse modulation
PM
process by which the amplitude of a carrier wave is varied following a specified law, resulting in a PM signal

3.27
(electromagnetic) radiation
phenomenon by which energy in the form of electromagnetic waves emanates from a source into space; energy transferred through space in the form of electromagnetic waves

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

[SOURCE: IEC 60050-161]

3.28
reflected power
power reflected by the load due to impedance mismatch between RF-source and load

3.29
shielded enclosure
screened room
mesh or sheet metallic housing designed expressly for the purpose of separating electromagnetically the internal and external environment

[SOURCE: IEC 60050-161]

3.30
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

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

where r is the absolute value of the coefficient of reflection

[SOURCE: IEC 60050-726]

3.31
transmission line system
TLS
field-generating device that works in a similar way to a TEM (transverse electromagnetic) wave generator

EXAMPLE Stripline, TEM cell, parallel plate.

4 General aim and practical use

The test methods, procedures, test instrumentation, and levels specified in ISO 11451 are intended to facilitate vehicle 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 device under test (DUT) more severely.

A single standard test may not reveal all the needed information about the DUT. It is thus necessary for users of ISO 11451 to anticipate the appropriate test conditions, select applicable parts of ISO 11451, and define function performance objectives. The main characteristics of each test method in ISO 11451-2 to ISO 11451-4 are presented in Table 1.

Table 1 — Main characteristics of test methods in ISO 11451

Part of ISO 11451	Applicable frequency range	Coupling to	Test severity parameter and unit	Provisions
ISO 11451-2 Off-vehicle radiation sources	10 kHz to 18 GHz	Components and wiring harness	Electric field (V/m)	Absorber-lined shielded enclosure required
ISO 11451-3 On-board transmitter simulation	1,8 MHz to 5,85 GHz	Components and wiring harness	Power (W)	Absorber-lined shielded enclosure recommended
ISO 11451-4 Bulk current injection (BCI)	1 MHz to 400 MHz	Wiring harness	Current (mA)	Shielded enclosure recommended

5 General test conditions

5.1 General

Unless otherwise specified, the following test conditions are common to all parts of ISO 11451:

— test temperature;

— supply voltage;

— modulation;

— dwell time;

— frequency step sizes;

— definition of test severity level;

— test signal quality.

NOTE The use of the same parameters as those used for the component test methods given in the corresponding parts of ISO 11451 will achieve better correlation.

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

— ±10 % for durations and distances;

— ±10 % for resistances and impedances;

— and the following magnitude accuracy:

  — ±1 dB for power meter including power sensor;

  — ±3 dB for field probe.

5.2 Test temperature

Heat is generated in the test facility when the vehicle is operated during the performance of the test. Sufficient cooling shall be provided to ensure that the engine does not overheat.

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

5.3 Supply voltage

5.3.1 Vehicle Low Voltage (LV) power supply

LV is used for d.c. operating voltages below 60 V (e.g. 12 V, 24 V, 48 V). For tests that require the vehicle engine to be running, the electrical charging system shall be functional. For tests where the vehicle engine is not required to be running, unless other values are specified in the test plan, the battery voltage shall be maintained above 12 V for 12 V systems and above 24 V for 24 V systems.

5.3.2 Hybrid or electric vehicle not connected to power mains

HV is used for operating voltages from 60 V to 1000 V d.c. The minimum high voltage value shall be defined in the test plan.

5.3.3 Hybrid or electric vehicle in charging mode (AC or DC)

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

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

5.4 Modulation

The characteristics of the DUT determine the type and frequency of modulation to be used. If no values or specific modulation techniques are agreed between the users of ISO 11451, the following shall be used:

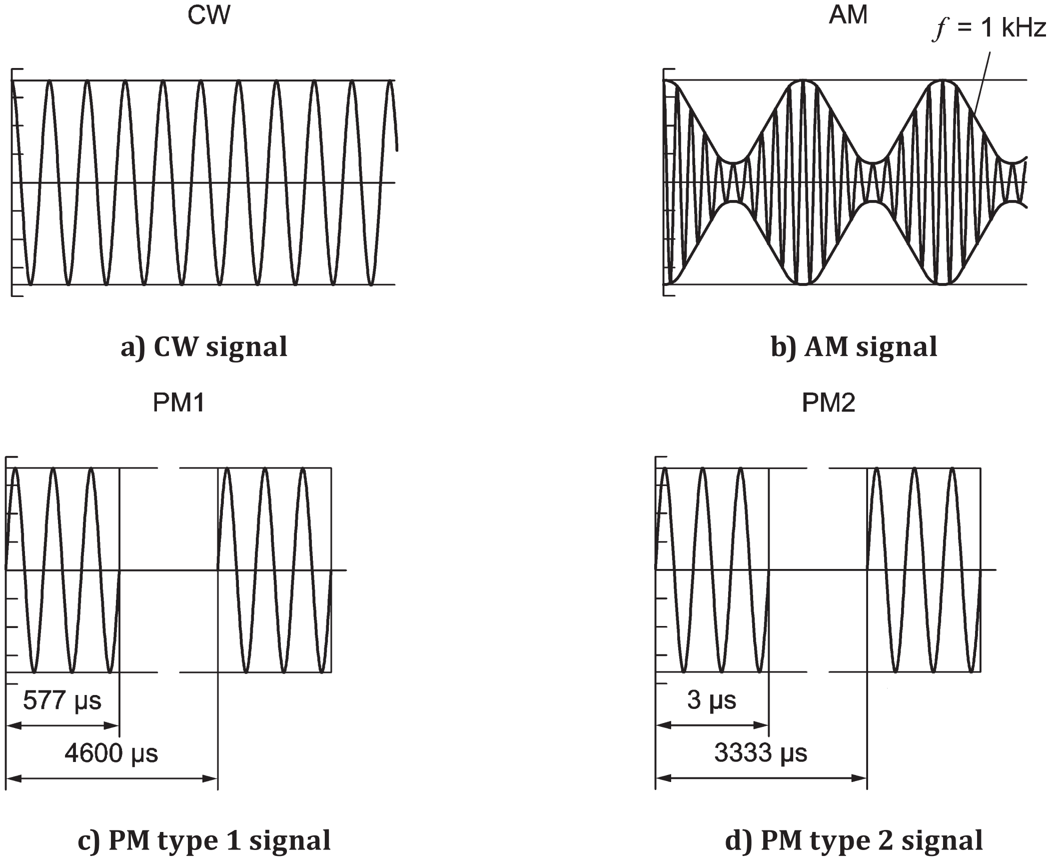
a) unmodulated sine wave (CW). See Figure 1 a);

b) sine wave amplitude modulated (AM) by 1 kHz sine wave at 80 % (modulation index m = 0,8) [see Annex C and Figure 1 b)];

c) sine wave pulse modulated type 1 (PM, similar to GSM), with ton = 577 µs and period = 4 600 µs [see Figure 1 c)];

d) sine wave pulse modulated type 2 (PM, similar to radar), with ton = 3 µs and period = 3333 µs; [see Figure 1 d)].

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



Key

f frequency

Figure 1 — Modulation

The following modulations should be used for all applicable parts of ISO 11451:

— CW: 0,01 MHz to 18 GHz;

— AM: 0,01 MHz to 800 MHz;

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

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

5.5 Dwell time

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

5.6 Frequency step sizes

All tests in ISO 11451 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 this part of ISO 11451 shall be documented in the test report.

Table 2 — Maximum frequency step sizes

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

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

5.7 Definition of test severity levels

The user should specify the test severity level or levels over the frequency range. The concept of FPSC is detailed in Annex A. For both the substitution and closed loop levelling methods, and for tests with unmodulated and amplitude-modulated signals, the test severity levels of ISO 11451 (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 C).

$$P_{AM} = \left[\left(2 + m^2\right) / 2\left(1 + m\right)^2 \right] P_{CW} \qquad (1)$$

where

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

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

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

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

5.8 Disturbance application

For disturbance application, see 7.2.4.

6 Instrumentation

6.1 AN, AMN, and AAN

The networks (AN, AMN, and AAN) to be used (when required by an individual test method) for a vehicle in charging mode connected to the power grid are defined in Annex B.

6.2 Test signal quality

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

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

NOTE When a specific part of ISO 11451 defines multiple polarization test, the harmonics characteristics need only be verified for one polarization.

7 Test procedure

7.1 Test plan

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

— vehicle test severity levels;

— vehicle/component monitoring conditions;

— frequency band(s);

— method(s) to be used;

— vehicle mode of operation;

— vehicle acceptance criteria;

— polarization;

— vehicle orientation;

— antenna location;

— test report content;

— any special instructions and changes from the standard test.

Some of the above items might not be applicable to all test methods.

7.2 Test methods

7.2.1 General

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

The following two methodologies are used in certain parts of ISO 11451.

7.2.2 Substitution

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

This method is carried out in two phases:

— calibration phase (without the vehicle and any ancillary equipment);

— test of the vehicle.

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

7.2.2.1 Calibration

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

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

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

When requested, the method and results for each calibration shall also be documented in the test report.

7.2.2.2 Vehicle test

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

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

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

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

where

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

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

L_{test} is the test severity level;

L_{cal} is the calibrated test severity level;

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

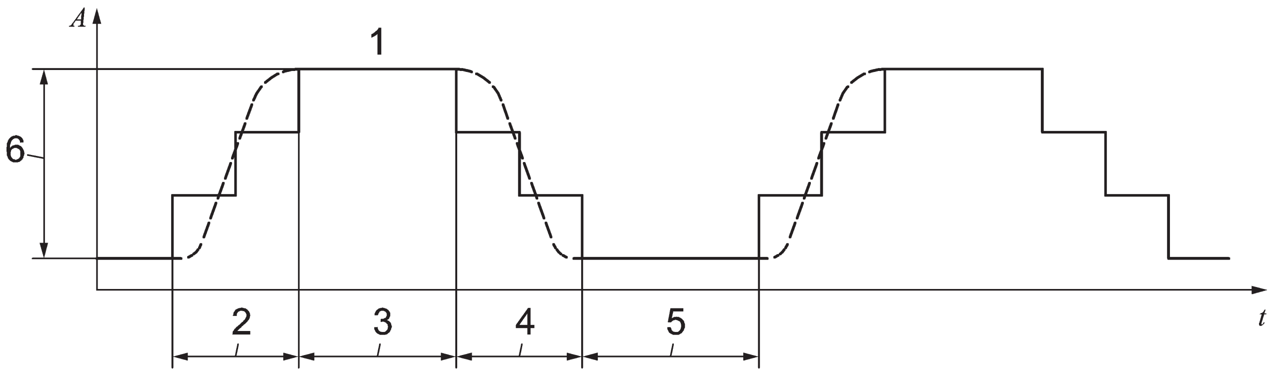
7.2.3 Closed loop levelling

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

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

7.2.4 Vehicle 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 following process (Figure 2). The method chosen and the associated parameters shall be defined in the test plan.



Key

1 specified signal level

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

3 dwell time (time of application ≥1 s)

4 signal fall time to be defined in the test plan

5 recovery time (time of recovery ≥0 s) for the DUT to be defined in the test plan

6 reduction of the test signal level for DUT recovery

Figure 2 — Example for disturbance application process

NOTE The users of this part of ISO 11451 should be aware of the following points to ensure that the tests are carried out satisfactorily:

— systems could be susceptible only at intermediate interference levels;

— sudden application of interference can cause errors;

— generator switching transients can cause faults in the DUT.

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

7.3 Test report

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

Annex A
(normative)

Function Performance Status Classification (FPSC)

A.1 General

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

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

2) a function can have one or several operating mode (e.g. low beam ON, low beam OFF, courtesy lighting ON, courtesy lighting OFF);

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

The functional performance status classification is applicable to each function.

A.2 FPSC approach

The approach is based on the following principles:

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

2) a function can be a simple On-Off operation or be as complex as data communication on a data bus.

It has to be emphasized that vehicle shall only be tested under the conditions, as described in ISO 11451 that represent the simulated automotive electromagnetic environments to which the devices would actually be subjected. This will help to ensure a technically and economically optimized design for potentially susceptible components and systems.

It should also be noted that this Annex is not intended to be a product specification and cannot function as one. It should be used in conjunction with a specific test procedure in ISO 11451. Therefore, no specific values for the test signal severity level are included in this Annex because they should be determined by the vehicle manufacturers and component suppliers. Nevertheless, using the concepts described in this Annex and by careful application and agreement between manufacturer and supplier, this Annex can be used to describe the functional status requirements for a specific device. This can then, in fact, be a statement of how a particular device can be expected to perform under the influence of the specified test signals.

A.3 Essential elements of FPSC

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

A.3.1 Function performance status

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

— This element is applicable to every single individual function of a vehicle and describes the operational status of the defined function during and after a test;

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

a) **Status I**

The function performs as designed during and after the test.

b) **Status II**

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

c) **Status III**

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

d) **Status IV**

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

A.3.2 Test severity level

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

A.4 FPSC approach example

A.4.1 General example of FPSC application

The following illustration demonstrates the relationship between the test signal severity levels (Severity Levels) and their corresponding function performance status classification.

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

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

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

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

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

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

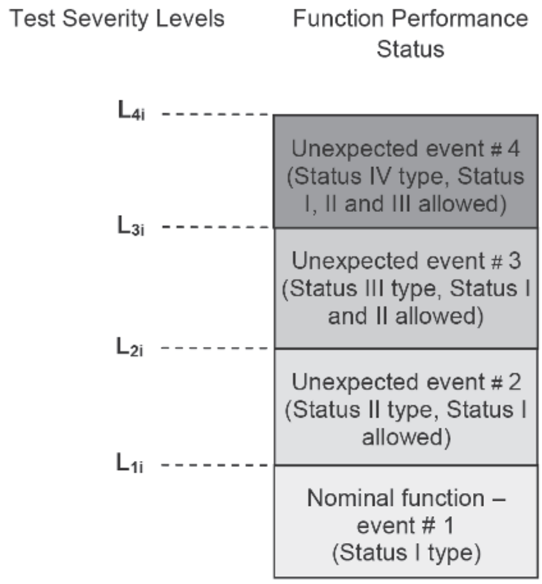


Figure A.1 — Illustration of function performance status classification

A.4.2 Classification of test severity levels

Examples of test severity levels are given in each part of ISO 11451.

Annex B
(normative)

Artificial Networks (AN), Artificial Mains Networks (AMN) and Asymmetric Artificial Networks (AAN)

B.1 General

Currently, different types of power supplies and power supply cabling are used for a vehicle in charging mode connected to the power grid (AC power mains, DC power supply). Therefore, it is necessary to use networks which provide specific load impedance and isolate the vehicle from the power supply.

— Artificial networks (AN): used for DC power supplies.

— Artificial mains networks (AMN): used only for AC power mains.

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

B.2 Artificial networks (AN)

For a vehicle in charging mode connected to a DC power supply, a 5µH/50Ω High Voltage Artificial Network (HV-AN) as defined in Figure B.1 shall be used.

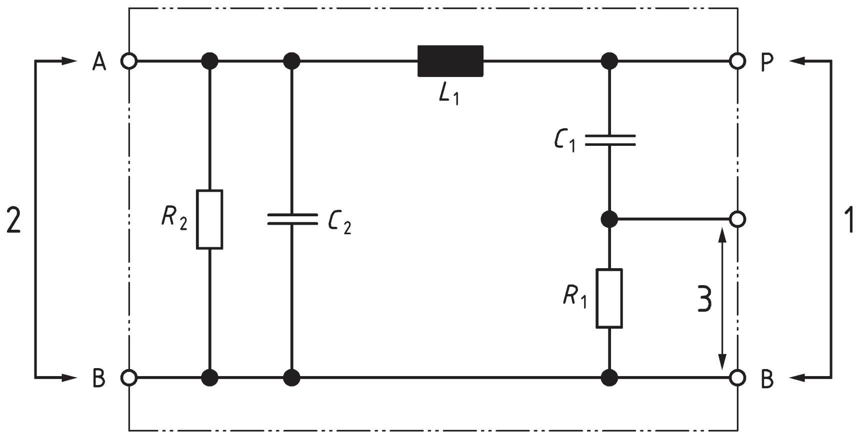
The HV-AN(s) shall be mounted directly on the ground plane. The grounding connection of the HV-AN(s) shall be bonded to the ground plane with a low inductivity connection.

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

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

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

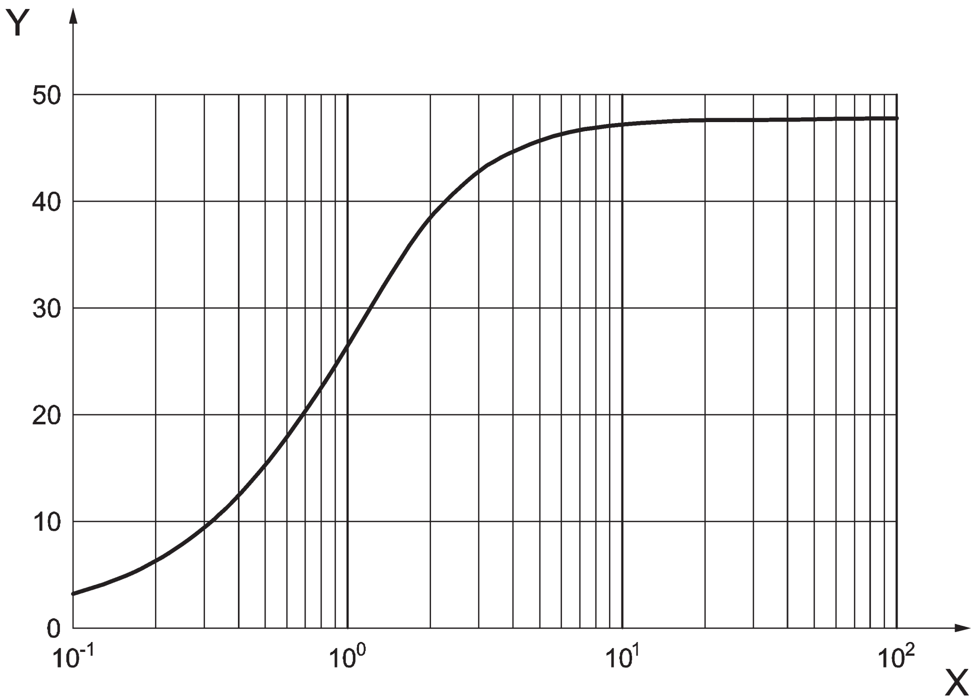
NOTE 2 The HV-AN isolation (decoupling factor) requirement are defined in CISPR 16-1-2, 4.7.1.



Key

1 port for the DUT
2 power supply port
3 measurement port
L_1 5 µH
C_1 0,1 µF
C_2 0,1 µF
R_1 1 kΩ
R_2 1 MΩ (discharging C2 to <50 Vdc within 60 s)

Figure B.1 — Example of 5 µH HV-AN schematic



Key

X frequency MHz
Y impedance Ohm

Figure B.2 — Characteristics of the HV-AN impedance

B.3 Artificial mains networks (AMN)

For a vehicle in charging mode connected to an AC power mains, a 50µH/50Ω-AMN as defined in CISPR 16-1-2, 4.3 edition 1.2 shall be used.

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

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

B.4 Asymmetric artificial network (AAN)

Currently, different types of communication system and communication cabling are used for the communication between charging station and vehicle. Therefore, a distinction between some specific cabling/operation types is necessary.

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

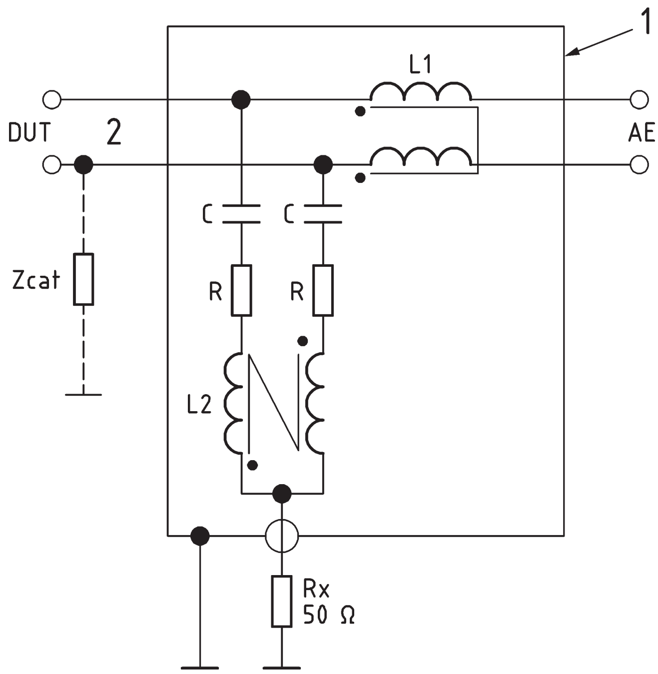
Measurement ports of AAN(s) shall be terminated with a 50 Ω load.

B.4.1 Symmetric communication lines

An asymmetric artificial network (AAN) to be connected between vehicle and charging station or any associated equipment (AE) used to simulate communication is defined in CISPR 16-1-2 Annex E, E.2 (T network circuit) (see example in Figure B.3).

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

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



Key

1	AAN metal case
2	balanced pair
C	4,7 µF
R	200 Ω
L1	2 × 38 mH
L2	2 × 38 mH
AE	associated equipment
DUT	device under test
Rx	receiver input

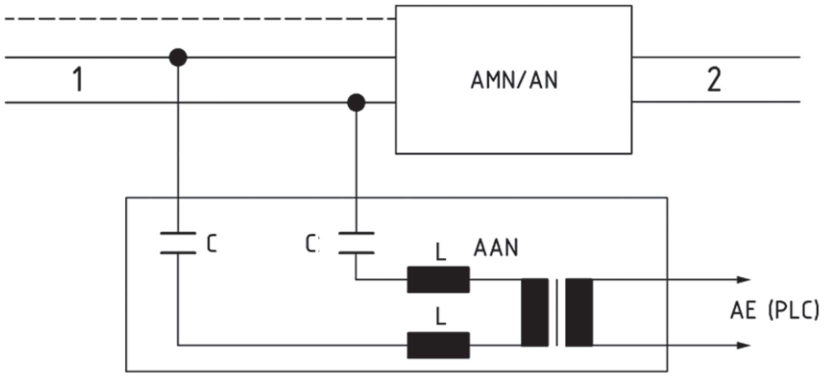
Figure B.3 — Example of an AAN for symmetric communication lines

B.4.2 PLC on power lines

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

If PLC communication cannot be ensured with original charging station and AMN or shall be simulated with use of an associated equipment (AE) (e. g. as a PLC modem) instead of an original charging station, it is necessary to add an AAN for PLC communication between PLC modem and the AMN (vehicle side) as defined in Figure B.4.

NOTE This AAN is not intended for any conducted emission measurement, but only to ensure adequate decoupling between PLC modem and power mains.



Key

1 vehicle

2 mains/power supply

C 4,7 nF

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

Figure B.4 — Example of AAN circuit of PLC on AC or DC powerlines

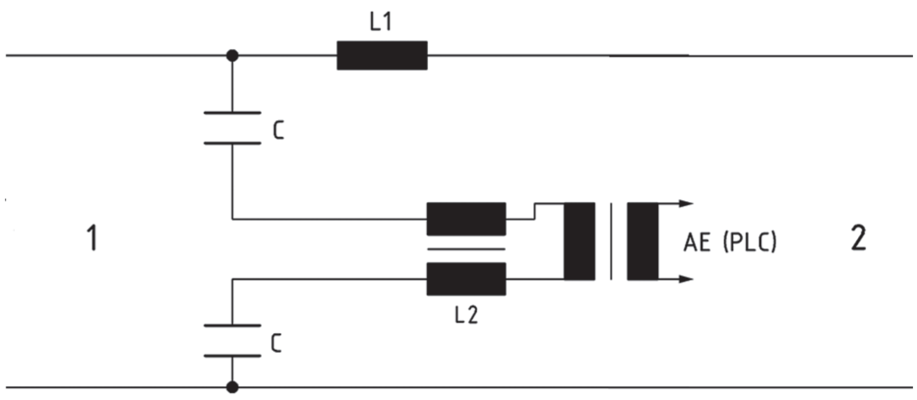
B.4.3 PLC (technology) on control pilot

Some communication systems use the control pilot line (versus PE) with a superimposed (high frequency) communication. Typically, the technology developed for powerline communication (PLC) is used for that purpose. On one hand, the communication lines are operated unsymmetrically, on the other hand, two different communication systems operate on the same line. Therefore, a special AAN shall be used as defined in Figure B.5.

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

The values of inductance and capacitance in the networks added for PLC on control pilot shown in Figure B.5 shall not induce any malfunction of communication between vehicle and AE or charging station. It can therefore be necessary to adapt these values to ensure proper communication.

NOTE This AAN is not intended for any conducted emission measurement, but only to ensure a controlled impedance of the pilot line (and PLC) seen from the component or vehicle side.



Key

1 vehicle

2 mains/power supply

C 2,2 nF

L1 100 μH

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

Figure B.5 — Example of AAN circuit for PLC on control pilot line

Annex C
(informative)

Constant peak test level

C.1 General

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

C.2 Unmodulated signal

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

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

where

E is the peak value of E_{CW};

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

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

$$P_{CW} = kE^2 \tag{C.2}$$

where

k is a proportionality factor which is constant for a specific test setup.

C.3 Modulated signal

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

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

where

E' is the peak amplitude of the unmodulated signal;

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

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

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

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

The total mean power for the amplitude-modulated signal, P_{AM}, is the sum of the power in the carrier component, 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

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

where

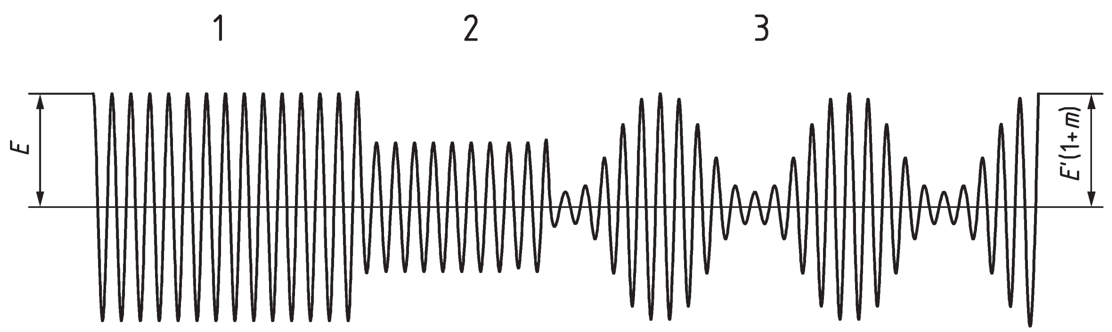
k is a proportionality factor which is constant for a specific test setup.

C.4 Peak conservation

C.4.1 General

For peak test level conservation, the peak amplitudes of the unmodulated and amplitude-modulated signals are defined to be identical, as shown in Figure C.1.

$$E_{CWpeak} = E_{AMpeak} \qquad \text{(C.5)}$$



Key

1 CW signal

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

3 AM signal

Figure C.1 — Peak conservation

There are two ways to adjust the signal to maintain peak conservation, as described in B.4.2 and B.4.3, respectively.

C.4.2 Measurement of modulated power

The relation between the mean power for the unmodulated signal, P_{CW}, and the mean power for the amplitude-modulated signal, P_{AM}, is then

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

therefore

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

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

$$P_{AM} = 0{,}407\,P_{CW} \qquad \text{(C.8)}$$

C.4.3 Measurement of unmodulated power before applying modulation

The relation between the mean power for the unmodulated signal, P_{CW}, and the mean power for the amplitude-non-modulated signal before applying modulation ($P_{CW,bm}$) is then

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

therefore

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

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

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

Bibliography

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

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

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