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**Radio Equipment and Systems (RES);
Electro-Magnetic Compatibility (EMC) standard
for wireless microphones and similar
Radio Frequency (RF) audio link equipment**

ETSI

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Foreword

This European Telecommunication Standard (ETS) was produced by the Radio Equipment and Systems (RES) Technical Committee of the European Telecommunications Standards Institute (ETSI).

Transposition dates	
Date of adoption of this ETS:	15 December 1995
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Introduction

Wireless radio microphone equipment operates with a continuous RF output signal and will normally be in continuous operation for a number of hours. The transmitter typically operates at a maximum radio frequency output power of 50 mW. Wireless radio microphones may be distinguished from other voice communication equipment (e.g. PMR) by the following operational characteristics:

- 1) wider audio bandwidth;
- 2) higher audio signal to noise ratio;
- 3) lower audio frequency distortion.

Aids for the handicapped, tour guides systems and similar constant RF devices operate in a similar manner to wireless microphones, but with variations of bandwidth and reduced RF output power.

RF audio link equipment conform to the same parameters as a wireless radio microphone but with a higher RF carrier power. RF audio link equipment is generally used for longer distance transmission, e.g. outside broadcast applications.

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1 Scope

This ETS covers the assessment of radio communication and ancillary equipment in respect of electromagnetic compatibility. Technical specifications related to the antenna port are not included in this standard. Such technical specifications are found in the relevant product standards for the effective use of the radio spectrum.

This ETS specifies the applicable EMC tests, the measurement methods, the limits and the minimum performance criteria for wireless microphones and similar RF audio link equipment operating in the frequency range 25 MHz to 4 GHz, and any associated ancillary equipment.

The environment classification used in this ETS refers to the environment classification used in the Generic Standards EN 50081-1 [2], EN 50082-1 [3], except the vehicular environment class which refers to ISO 7637 [4].

The EMC technical specifications have been selected to ensure an adequate level of compatibility for apparatus at residential, commercial, light industrial and vehicular environments. The levels however do not cover extreme cases which may occur in any location but with a low probability of occurrence.

This ETS may not cover those cases where a potential source of interference, which is producing individually repeated transient phenomena or a continuous phenomena, is permanently present, e.g. a radar or broadcast site in the near vicinity. In such a case it may be necessary to use special mitigation measures applied to either the source of the interference or to the interfered part of both.

If other transmitters or receivers are combined with either wireless radio microphones or RF audio link equipment, they shall be tested to their appropriate EMC standard.

Compliance of radio equipment to the technical specifications of this ETS does not signify compliance to any requirements related to the use of the equipment (licensing requirements).

Compliance to this ETS does not signify compliance to any safety requirement. However, it is the responsibility of the assessor of the equipment that an observation regarding the equipment becoming dangerous or unsafe as a result of the application of the tests defined in this ETS should be recorded in the test report.

2 Normative references

This ETS incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and relate to the publications listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this ETS only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

- [1] 89/336/EEC: "Council Directive on the approximation of the laws of the Member States relating to electromagnetic compatibility".
- [2] EN 50081-1 (1992): "Electromagnetic compatibility - Generic emission standard. Part 1: Residential, commercial and light industry".
- [3] EN 50082-1 (1992): "Electromagnetic compatibility - Generic immunity standard. Part 1: Residential, commercial and light industry".
- [4] ISO 7637 (1990): "Road vehicles, Electrical disturbance by conducting and coupling" Part 1: "Passenger cars and light commercial vehicles with nominal 12 V supply voltage".

ISO 7637 (1990): "Road vehicles, Electrical disturbance by conduction and coupling". Part 2: "Commercial vehicles with nominal 24 V supply voltage, Electrical transient conduction along supply lines only".
- [5] EN 55022: (1987): "Limits and methods of measurement of radio interference characteristics of information technology equipment".

- [6] CISPR Publication No. 16-1: "Specification for radio disturbance and immunity measuring apparatus and methods".
- [7] ENV 50140: "Basic immunity standard - Radiated, radio-frequency, electromagnetic fields".
- [8] IEC 1000-4-2 : (1995) Part 4: "Testing and measurement techniques".Section 2: Electrostatic discharge immunity test".
- [9] IEC 1000-4-4: (1995) Part 4: "Testing and measurement techniques - Section 4: Electrical fast transient/burst immunity test".
- [10] ENV 50141: "Basic immunity standard - Conducted disturbances induced by radio-frequency fields."
- [11] IEC 1000-4-11 (1994): Part 4: "Testing and measurement techniques - Section 11: Voltage dips, short interruptions and voltage variations immunity tests".
- [12] ENV 50142: "Electromagnetic compatibility - Basic immunity standard - Surge immunity tests".
- [13] prETS 300 339: "Radio Equipment and Systems (RES); General Electro-Magnetic Compatibility (EMC) for radio equipment".
- [14] ETS 300 422: "Radio Equipment and Systems (RES); Technical characteristics and test methods for wireless microphones in the 25 MHz to 3 GHz frequency range".
- [15] ETS 300 454: "Radio Equipment and Systems (RES); Technical characteristics and test methods in the 25 MHz - 3 GHz frequency range for wide band audio links".

3 Definitions and Abbreviations

3.1 Definitions

For the purpose of this ETS, the following definitions apply:

vehicle battery: The battery used for the principle operation of the vehicle, i.e. the starting of the vehicle.

ancillary equipment: Equipment (apparatus), used in connection with a receiver, transmitter or transceiver is considered as an ancillary equipment (apparatus):

- the equipment is intended for use in conjunction with a receiver, transmitter or transceiver to provide additional operational and/or control features to the radio equipment (e.g. to extend control to another position or location); and
- the equipment cannot be used on a stand alone basis to provide user functions independently of a receiver, transmitter or transceiver; and
- the receiver, transmitter or transceiver to which it is connected, is capable of providing some intended operation such as transmitting and/or receiving without the ancillary equipment (i.e. it is not a sub unit of the main equipment essential to the main equipment basic functions).

integral antenna: An antenna designed to be connected to the equipment without the use of a 50 Ω external connector and considered to be part of the equipment. An integral antenna may be fitted internally or externally to the equipment.

port: A particular interface of the specified apparatus with the external electromagnetic environment (see figure 1).

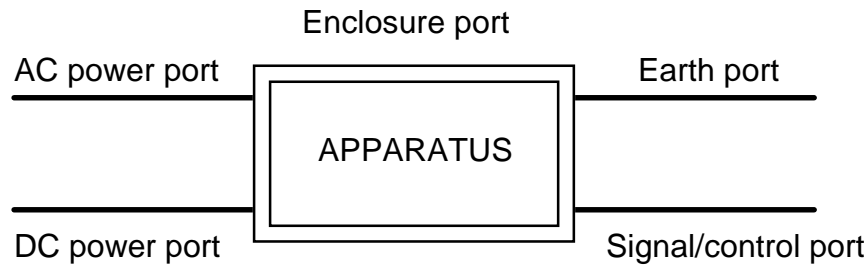


Figure 1: Examples of ports

A cable port is any connection point to an equipment intended for connection of cables to or from that equipment.

enclosure port: The physical boundary of the apparatus through which electromagnetic fields may radiate or impinge.

manufacturer: The legal entity responsible under the terms of the Council Directive, 89/336/EEC [1], for placing the product on the market.

radio communications equipment: An apparatus which includes one or more transmitters and/or receivers and/or parts thereof. This type of equipment (apparatus) can be used in a fixed, mobile or a portable application.

companding: A method of audio processing that compresses the audio dynamic range before transmission and then provides matching expansion of the signal in the receiver. Used to improve the audio performance in the RF link.

3.2 Abbreviations

EUT Equipment Under Test.

4 General test conditions

4.1 Test conditions

The equipment shall be tested under normal test conditions contained in the relevant product and basic standards or in the information accompanying the equipment, which are within the manufacturers declared range of humidity, temperature and supply voltage.

The test conditions shall be recorded in the test report.

For the purpose of test, body worn or hand held transmitters shall be mounted on a non-conductive stand at least 0,8 m from any conducting surface. The EUT and any other equipment required for the evaluation shall be connected in a manner typical of normal intended use.

Whenever the EUT is provided with a detachable antenna, the EUT shall be tested with the antenna fitted in a manner typical of normal intended use.

For immunity tests, if the equipment is of a category which permits it, a communications link shall be established at the start of the test and maintained during the test. Test modulation, test arrangement etc., as specified in this ETS, subclauses 4.2, 4.3, 4.4 and 4.5 shall apply and the conditions shall be as follows:

- the transmitter shall be operated at its normal maximum output power modulated with a suitable test signal (see subclause 4.2);
- for stand alone receivers or receivers of transceivers operating in the simplex mode, the wanted RF input signal, coupled to the receiver, shall be modulated with a suitable test signal (see subclause 4.4);

- for duplex transceivers, the wanted RF input signal, coupled to the receiver, shall be modulated with a suitable test signal (see subclause 4.2). The transmitter shall be operated at its normal maximum output power, modulated with the test signal, coupled to the transmitter from the output of the receiver (repeater mode).

4.2 Arrangements for test signals at the input of the transmitter

The transmitter shall be modulated with a suitable test signal from an internal or external signal source. It shall be possible to verify that a communications link is established and maintained.

In the case of transmitters designed to operate from an integral or dedicated microphone (see figure 3) it shall be permissible to use an acoustic coupling device to inject the test signal. The acoustic coupling device may be provided by the manufacturer (see figure 4).

In the case of equipment which can use a variety of audio capsules, the manufacturer shall declare the type of capsule, e.g. dynamic, electret or condenser, to be provided with the system. Only one capsule shall be tested. All other capsules shall be deemed as compliant. The transmitter shall be tested at its most sensitive input with the test capsule.

In the case of equipment not designed to use integral or dedicated microphone, the test signal shall be fed in electrical form to the most sensitive input socket (see figure 2) using maximum length cables as normally supplied by the manufacturer with the equipment.

The test signal shall be a 1 kHz sine wave at a level declared by the manufacturer to obtain 100 % audio modulation.

The manufacturer may provide a suitable companion receiver that can be used to set up a communications link. In this case a suitable attenuator in the companion receiver input may be necessary, see annex A for further details.

4.3 Arrangements for test signals at the output of the transmitter

The measuring equipment used to monitor the output signal of the transmitter shall be located outside of the test environment. Adequate measures shall be taken to protect the measuring equipment from the effect of all interferences (e.g. radiated fields and conducted interferences).

Where the equipment incorporates an external RF antenna connector the output signal of the transmitter may be coupled to the receiving measuring equipment via a shielded transmission line, such as a coaxial cable, to enable a communications link to be established and maintained.

In the case of an integral antenna equipment not provided with an external RF antenna connector, the output signal of the transmitter shall be coupled to another antenna located within the test environment enabling a communications link to be established and maintained. This antenna shall be coupled to the receiving measuring equipment.

4.4 Arrangements for test signals at the input of the receiver

The wanted input signal to the receiver should be modulated with a suitable test signal corresponding to 100 % audio modulation (maximum channel loading). If it is not appropriate to provide a modulated signal to the receiver, the test may be performed using an unmodulated wanted input signal. It shall be possible to verify that a communications link is established and maintained.

The level and make up of the test signal shall be declared by the manufacturer. The level chosen shall be set to a value 60 dB above the threshold sensitivity of the receiver. The level used shall be recorded in the test report.

The manufacturer may provide a suitable companion transmitter that can be used to set up a communications link. In this case a suitable attenuator in the EUT input may be necessary.

Where the equipment under test incorporates an external RF connector, the wanted signal, to establish a communication link may be delivered to that connector by a coaxial cable. The measuring equipment of the wanted input signal shall be located outside the test environment. Adequate measures shall be taken to avoid the effect of the unwanted signals on the measuring equipment.

Where the EUT does not normally incorporate an external RF port (integral antenna equipment), the wanted signal, to establish a communication link, shall be delivered from the equipment to an antenna located (see figure 5) within the test environment. The measuring equipment of the wanted signal shall be located outside of the test environment. Adequate measures shall be taken to avoid the effect of the unwanted signals on the measuring equipment.

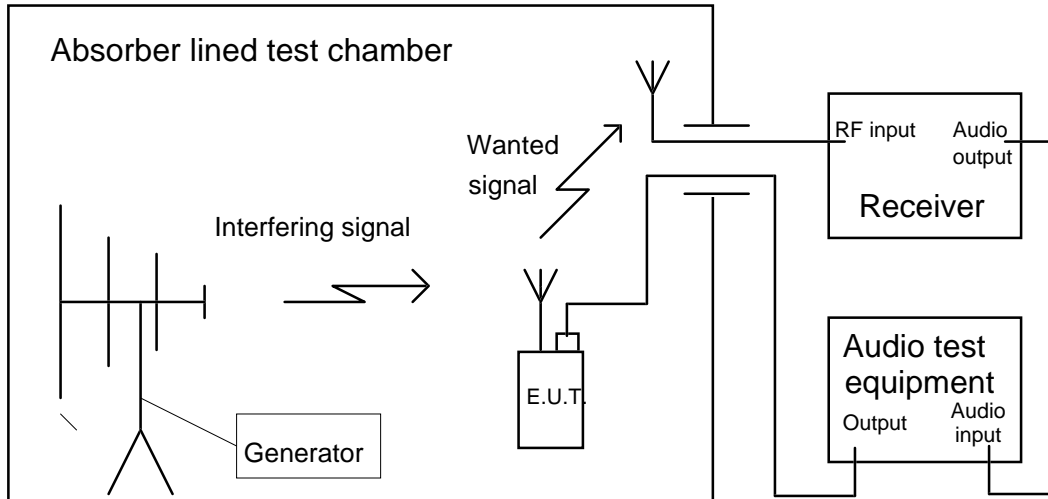


Figure 2: Test configuration for integral antenna; transmitter operation - electrical input

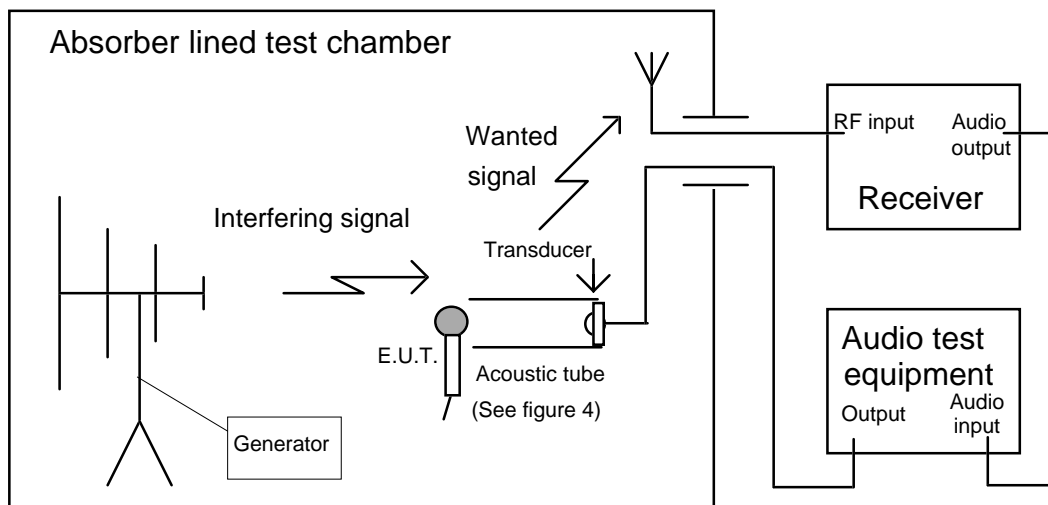


Figure 3: Test configuration for integral antenna; transmitter operation - acoustic input

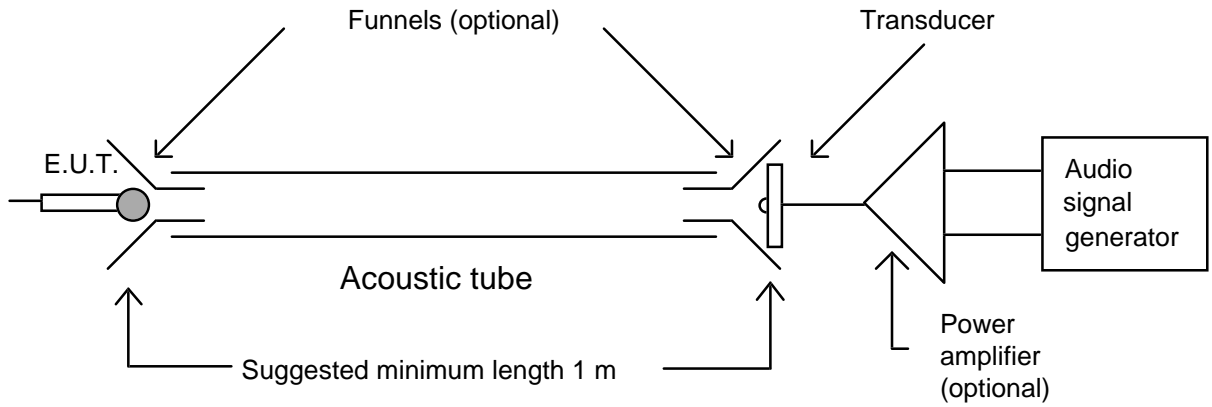
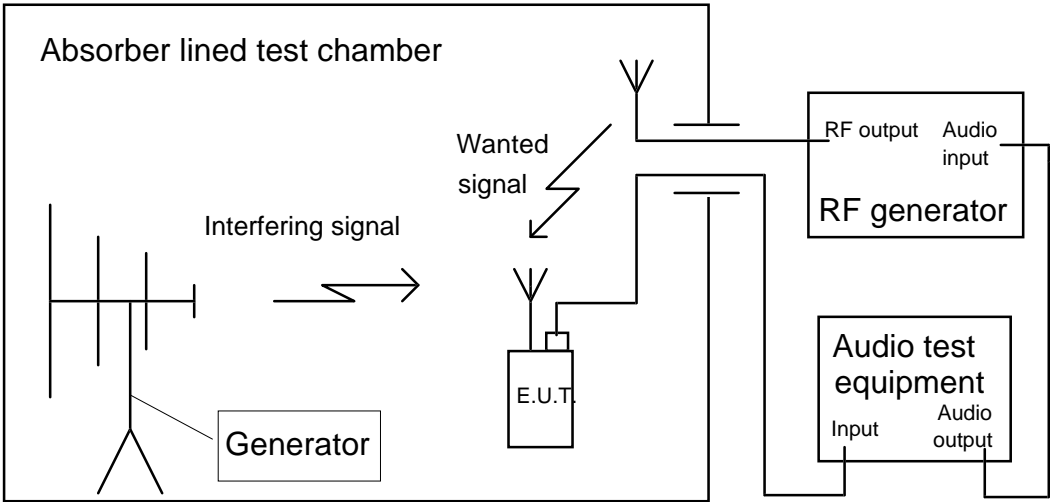


Figure 4: Example of acoustic coupling jig



NOTE: RF generator may be a companion transmitter sited inside the test chamber if necessary.

Figure 5: Test configuration for integral antenna; receiver operation

4.5 Arrangements for test signals at the output of the receiver

Frequencies on which the equipment is intended to operate are excluded from immunity tests with either conducted or radiated unwanted RF signals. These RF tests exclusions are referred to as "exclusion bands".

The equipment used for monitoring the maintenance of the communications link shall be located outside of the test environment.

The audio frequency output of the equipment should be suitably coupled to a SINAD measuring system outside of the test environment. The characteristics of the SINAD measuring system shall be such that the upper - 3 dB frequency of the detector part of the SINAD measuring system is to exceed 16 kHz, and the test system electrical measurement flatness error between 40 Hz and 16 kHz is not to exceed ± 2 dB. The choice of coupling shall be recorded in the test report.

Adequate measures shall be taken to protect the measuring equipment from the effect of all interference (e.g. radiated fields and conducted interferences).

4.6 Receiver and receivers of transceiver exclusion band

The exclusion band for receivers and receivers of transceivers is the frequency range determined by the switching range, as declared by the manufacturer, extended as follows:

- 1) Class 1 and 2 (as defined in subclause 5.4):
 - the lower frequency of the exclusion band is the lower frequency of the switching range, minus 5 % of the centre frequency of the switching range;
 - the upper frequency of the exclusion band is the upper frequency of the switching range, plus 5 % of the centre frequency of the switching range;
- 2) Class 3 (as defined in subclause 5.4):
 - the lower frequency of the exclusion band is the lower frequency of the switching range, minus 5 % of the centre frequency of the switching range, or minus 10 MHz, whichever will result in the lowest frequency;
 - the upper frequency of the exclusion band is the upper frequency of the switching range, plus 5 % of the centre frequency of the switching range, or plus 10 MHz, whichever will result in the highest frequency.

The switching range is the maximum frequency range over which the receiver can be operated without reprogramming or realignment.

The manufacturer shall state the class of equipment on the documentation accompanying the product, and must declare the class to the test house in the form of a manufacturer's declarations.

4.7 Transmitter exclusion band

The lower frequency of the exclusion band is the lower frequency of the switching range, minus 5 % of the centre frequency of the switching range.

The upper frequency of the exclusion band is the upper frequency of the switching range, plus 5 % of the centre frequency of the switching range.

The switching range is the maximum frequency range over which the receiver or transmitter can be operated without reprogramming or realignment.

4.8 Narrow band responses of stand alone receivers or receivers which are part of a transceiver

Responses on receivers or receivers of transceivers occurring during the test at discrete frequencies which are narrow band responses (spurious responses), are identified by the following method.

If during the test an unwanted signal creates a degradation of performance of the audio output resulting from the wanted signal, it is necessary to establish whether the degradation of performance is due to a narrow band response or a wide band phenomena. Therefore, the unwanted signal frequency is increased by an amount equal to twice the bandwidth of the receiver IF filter immediately preceding the demodulator, as declared by the manufacturer. The test is repeated with the frequency of the unwanted signal decreased by the same amount.

If the degradation of performance disappears, then the response is considered as a narrow band response.

If the degradation of performance does not disappear, this may be due to the fact that the offset has made the frequency of the unwanted signal correspond to the frequency of another narrow band response. Under these circumstances the procedure is repeated with the increase and decrease of the frequency of the unwanted signal adjusted two and one half times the bandwidth previously referred to.

If the degradation of performance does not disappear, the phenomena is considered wide band and therefore an EMC problem and the equipment fails the test.

Narrow band responses are disregarded.

5 Performance assessment

5.1 General

The manufacturer shall at the time of submission of the equipment for test, supply the following information which shall be recorded in the test report:

- the primary functions of the radio equipment to be tested during and after the EMC testing;
- the intended functions of the EUT which shall be in accordance with the documentation accompanying the equipment;
- the ancillary equipment to be combined with the radio equipment for testing;
- the method to be used to verify that a communications link is established and maintained;
- the user-control functions and stored data that are required for normal operation and the method to be used to assess whether these have been lost after EMC stress;
- an exhaustive list of ports, classified as either ac power, dc power or signal/control;
- the bandwidth of the IF filter immediately preceding the demodulator.

5.2 Equipment which can provide a communications link

If the category of the radio equipment or combination of a radio equipment and ancillary equipment permits the establishment of a communications link, the test modulation, test arrangement etc. as required in clause 4, apply.

5.3 Equipment which does not provide a communications link

If the equipment is of a category which does not permit a communications link to be established or in the case of ancillary equipment tested on a stand alone basis (see clause 6) the manufacturer shall define the method of test to determine the acceptable level of performance or degradation of performance during and/or after the test. The manufacturer shall provide the following:

- the pass/fail criteria for the EUT;
- the method of observing a degradation of performance of the equipment.

The assessment of the degradation of performance which shall be carried out during and/or at the conclusion of the tests, shall be simple, but at the same time give adequate proof that the primary functions of the equipment are operational.

5.4 Pass or fail criteria

The system shall be tested for SINAD before and after immunity testing and the results recorded, (see clause 9).

The equipment shall meet one of the following classes when subject to EMC stress:

Intended Use		
Class 1	30 dB SINAD	Professional entertainment
Class 2	20 dB SINAD	Domestic entertainment
Class 3	12 dB SINAD	Communications

The information required to enable use in accordance with the intended purpose of the product, declared as "professional entertainment" (Class 1), "domestic entertainment" (Class 2), or "communications" (Class 3), shall be contained in the accompanying user product documentation.

The EUT, when coupled through the test equipment and not subject to EMC stress shall be capable of producing a SINAD figure of at least 3 dB above the class limit.

5.5 Equipment classification

Portable equipment or combinations of equipment also intended for normal use whilst being powered by the vehicle battery shall additionally be considered as vehicular mobile equipment.

Portable or mobile equipment or combinations of equipment declared as capable of being powered for intended use by ac mains shall additionally be considered as ac mains equipment.

If the manufacturer provides a range of different ac mains powered equipment all being compliant and carrying the CE mark then the tests on the ac mains port only need to be carried out with one of the power supplies, (i.e. it is the input port of the equipment being assessed and not the power supply).

5.6 Ancillary equipment

At the manufacturers discretion an ancillary equipment may be:

- declared compliant separately from a receiver, transmitter or transceiver to all the applicable immunity and emission clauses of this ETS;
- declared compliant to another appropriate harmonized EMC standard;
- tested with it connected to a receiver, transmitter or transceiver, in which case compliance shall be demonstrated to the appropriate clauses of this ETS.

In each case, compliance enables the ancillary equipment to be used with different receivers, transmitters, or transceivers.

6 Performance criteria

The equipment shall meet the minimum performance criteria as specified in the following subclauses as appropriate.

6.1 General performance criteria

The equipment shall meet the performance criteria as given in table 1 including the associated notes 1 and 2.

The performance criteria A, B and C as indicated in table 1 shall be used in the following manner:

- performance criteria A for immunity tests with phenomena of a continuous nature;
- performance criteria B for immunity tests with phenomena of a transient nature;
- performance criteria C for immunity tests with power interruptions exceeding a certain period of time;

unless specified otherwise.

Table 1: Performance criteria

Criteria	During test	After test
A	Operate as intended; Degradation of performance (note 1); No loss of function.	Operate as intended; No degradation of performance (note 2); No loss of function.
B	Loss of function (one or more).	Operate as intended; No degradation of performance (note 2); Functions self-recoverable.
C	Loss of function (one or more).	Operate as intended; No degradation of performance (note 2); Functions recoverable by the operator.
<p>NOTE 1: Degradation of performance during the test is understood as a degradation to a level not below a minimum performance level specified by the manufacturer for the use of the apparatus as intended. In some cases the specified minimum performance level may be replaced by a permissible degradation of performance.</p> <p>If the minimum performance level or the permissible performance degradation is not specified by the manufacturer then either of these may be derived from the product description and documentation (including leaflets and advertising) and what the user may reasonably expect from the apparatus if used as intended (see subclause 5.4).</p> <p>NOTE 2: No degradation of performance after the test is understood as no degradation below a minimum performance level specified by the manufacturer for the use of the apparatus as intended. In some cases the specified minimum performance level may be replaced by a permissible degradation of performance. After the test no change of actual operating data or user retrievable data is allowed.</p> <p>If the minimum performance level or the permissible performance degradation is not specified by the manufacturer then either of these may be derived from the product description and documentation (including leaflets and advertising) and what the user may reasonably expect from the apparatus if used as intended (see subclause 5.4).</p>		

6.2 Performance criteria for equipment capable of establishing a communications link

The establishment of the communications link at the start of the test, the maintenance of the communications link and the assessment of the recovered signal information, e.g. an audio signal, shall be used as the performance criteria to ensure that the essential functions of the transmitter and/or receiver are evaluated during and after the test.

The equipment shall meet the minimum performance criteria as specified for the appropriate category of equipment in the appropriate part of subclauses 6.4, 6.5, 6.6 and 6.7.

6.3 Performance criteria for equipment that is not capable of establishing a communications link

If the equipment is of a category which does not permit a communications link to be established or in the case of ancillary equipment being tested on a stand alone basis the manufacturer shall declare, for inclusion in the test report, the specification for an acceptable level of performance or degradation of performance during and/or after testing, as required by this ETS in subclause 6.1. The performance specification shall be included in the product description and documentation.

The performance criteria specified by the manufacturer shall provide, as a minimum, the same degree of immunity protection as specified in subclause 6.1 above.

6.4 Performance criteria for Continuous phenomena applied to Transmitters (CT)

If the equipment is in a general category including ancillary equipment tested on a stand alone basis, the performance criteria:

- A for class 1 equipment;
- C for classes 2 and 3 equipment;

as given in table 1, shall apply.

If the equipment is of a category that permits a communications link to be established the following procedure applies:

- during each individual exposure in the test sequence it shall be verified, by appropriate means supplied by the manufacturer, that the communications link is maintained;
- at the conclusion of the test the EUT shall operate as intended with no loss of user control functions or stored data, as declared by the manufacturer, and the communications link shall have been maintained during the test.

Where the EUT is a transmitter only, and a standby mode is provided, tests shall be repeated with the EUT in standby mode to ensure that unintentional transmission does not occur.

6.5 Performance criteria for Transient phenomena applied to Transmitters (TT)

If the equipment is in a general category including ancillary equipment tested on a stand alone basis, the performance criteria B as given in table 1 shall apply, except for measurements where it is explicitly stated that the communications link need not be maintained in which case performance criteria C from table 1, shall apply.

If the equipment is of a category that permits a communications link to be established the following procedure applies:

- at the conclusion of each exposure in the test sequence the EUT shall operate with no user noticeable loss of the communications link;
- at the conclusion of the total test comprising of a series of individual exposures the EUT shall operate as intended with no loss of user control functions or stored data, as declared by the manufacturer, and the communications link shall have been maintained during the test.

Where the EUT is a transmitter only, and a standby mode is provided, tests shall be repeated with the EUT in standby mode to ensure that unintentional transmission does not occur.

6.6 Performance criteria for Continuous phenomena applied to Receivers (CR)

This subclause applies to stand alone receivers, or receivers which are part of simplex or duplex transceivers.

If the equipment is in a general category including ancillary equipment tested on a stand alone basis, the performance criteria:

- A for class 1 equipment;
- C for classes 2 and 3 equipment ;

as given in table 1, shall apply.

If the equipment is of a category that permits a communications link to be established the following procedure applies:

- during each individual exposure in the test sequence it shall be verified, by appropriate means supplied by the manufacturer, that the communications link is maintained;
- at the conclusion of the test the EUT shall operate as intended with no loss of user control functions or stored data, as declared by the manufacturer, and the communications link shall have been maintained during the test.

Where the EUT is a transceiver, under no circumstances shall the transmitter operate unintentionally during the test.

6.7 Performance criteria for Transient phenomena applied to Receivers (TR)

This subclause applies to stand alone receivers, or receivers which are part of simplex or duplex transceivers.

If the equipment is in a general category including ancillary equipment tested on a stand alone basis, the performance criteria B as given in table 1 shall apply, except for measurements where it is explicitly stated that the link need not be maintained in which case performance criteria C from table 1 shall apply.

If the equipment is of a category that permits a communications link to be established the following procedure applies:

- at the conclusion of each exposure in the test sequence the EUT shall operate with no user noticeable loss of the communications link;
- at the conclusion of the total test comprising of a series of individual exposures the EUT shall operate as intended with no loss of user control functions or stored data, as declared by the manufacturer, and the communications link shall have been maintained during the test.

Where the EUT is a transceiver, under no circumstances shall the transmitter operate unintentionally during the test.

7 Applicability overview tables

7.1 Emission

Table 2: Emission applicability

Application	Equipment test requirement			Reference clause in this ETS	Reference document
	AC mains powered	Vehicle battery powered	Portable or other dc power (see note)		
Enclosure	applicable	applicable	applicable	8.2	EN 55022 [5]
DC power in/out	applicable	applicable	applicable	8.3	EN 55022 [5] CISPR 16-1 [6]
AC mains	applicable	not applicable	not applicable	8.4	EN 55022 [5]
NOTE:	This includes a protected dc supply within a vehicle which is isolated or separated from the vehicle battery.				

7.2 Immunity

Table 3: Immunity applicability

Phenomena	Application	Equipment test requirement			Reference clause in this ETS	Reference document
		AC mains power	Vehicle battery powered	Portable or other dc power (see note)		
RF electro-magnetic field 80 to 1 000 MHz	Enclosure	applicable	applicable	applicable	9.2	ENV 50140 [7]
Electrostatic discharge	Enclosure	applicable	applicable	applicable	9.3	IEC 1000-4-2 [8]
Fast transient common mode	Signal & control ports, dc & ac power input ports	applicable	not applicable	not applicable	9.4	IEC 1000-4-4 [9]
RF common mode 0,15 to 80 MHz current clamp injection	Signal & control ports, dc & ac power input ports	applicable	applicable	not applicable	9.5	ENV 50141 [10]
Transients and surges	DC power input ports	not applicable	applicable	not applicable	9.6	ISO 7637 [4] Part 1 and 2
Voltage dips and interruptions	AC mains power input ports	applicable	not applicable	not applicable	9.7	IEC 1000-4-11 [11]
Transients, common and differential mode	AC mains power input ports	applicable	not applicable	not applicable	9.8	ENV 50142 [12]
<p>NOTE: This includes a protected dc supply within a vehicle which is isolated or separated from the vehicle battery.</p>						

8 Test methods for emission tests of transmitters and/or receivers and/or ancillary equipment

8.1 Test configuration

This subclause defines the requirements for test configuration for tests in the following subclauses and are as follows:

- the measurement shall be made in the operation mode producing the largest emission in the frequency band being investigated consistent with normal applications;
- the equipment shall be configured in a manner which is representative of a normal/typical operation, where practical;
- an attempt shall be made to maximize the detected radiated emission for example by moving the cables of the equipment;
- if the equipment is part of a system, or can be connected to ancillary equipment, then it shall be acceptable to test the equipment while connected to the minimum configuration of ancillary equipment necessary to exercise the ports;

- the configuration and mode of operation during the measurements shall be precisely noted in the test report;
- if the equipment has a large number of ports, then a sufficient number shall be selected to simulate actual operation conditions and to ensure that all the different types of termination are tested;
- ports which in normal operation are connected shall be connected to an ancillary equipment or to a representative piece of cable correctly terminated to simulate the impedance of the ancillary equipment. RF input/output ports shall be terminated by a non-radiating load;
- the tests shall be carried out at a point within the specified normal operating environmental range at the rated supply voltage for the equipment.

8.2 Enclosure - ancillary equipment

This test is applicable to ancillary equipment.

This test shall be performed on :

- a representative configuration of the ancillary equipment; or
- a representative configuration of radio and ancillary equipment.

8.2.1 Definition

This test assesses the ability of equipment to limit any spurious radiation from the enclosure of ancillary equipment.

8.2.2 Test method

The test method shall be in accordance with EN 55022 [5].

8.2.3 Limits

The EUT shall meet the Class B limits according to EN 55022 [5] shown in table 4 (10 m measuring distance).

Table 4: Limits for spurious radiation (Class B)

Frequency range	Limit (quasi-peak)
30 to 230 MHz	30 dB μ V/m
> 230 to 1 000 MHz	37 dB μ V/m

8.3 DC power input/output port

This test is applicable for equipment under test which may have dc cables longer than three (3) m.

This test shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

8.3.1 Definition

This test assesses the ability of transmitters, receivers, transceivers and ancillary equipment to limit their internal noise from being present on the dc power input/output ports.

8.3.2 Test method

For equipment with a current consumption below 16 A the test method shall be in accordance with EN 55022 [5] and the Line Impedance Stabilizing Networks (LISNs) shall be connected to a dc power source.

For equipment with a current consumption above 16 A the dc power ports shall be connected to 5 μ H Line Impedance Stabilizing Networks (LISNs), with 50 Ω impedance measurement ports. The LISNs shall be in accordance with the requirements of section 2, CISPR Publication No. 16-1 [6].

A measuring receiver shall be connected to each LISN measurement port in turn and the conducted emission recorded. The LISN measurement ports not being used for measurement shall be terminated with a 50 Ω load.

The equipment shall be installed with a ground plane as defined in EN 55022 [5] subclause 9.3. The reference earth point of the LISNs shall be connected to the reference ground plane with a conductor as short as possible.

The measurement receiver shall be in accordance with the requirements of section one of CISPR Publication No 16-1 [6].

8.3.3 Limits for conducted RF signals

The equipment shall meet the limits below (including the average limit and the quasi-peak limit) when using, respectively, an average detector receiver and a quasi-peak detector receiver and measured in accordance with the method described in subclause 8.3.2. If the average limit is met when using a quasi-peak detector, the equipment shall be deemed to meet both limits and measurement with the average detector receiver is unnecessary.

The EUT shall meet the Class B limits according to EN 55022 [5] shown in table 5.

Table 5: Limits for conducted RF signals (Class B)

Frequency range	Quasi-peak	Average
0,15 to 0,5 MHz	66 - 56 dB μ V	56 - 46 dB μ V
> 0,5 to 5 MHz	56 dB μ V	46 dB μ V
> 5 to 30 MHz	60 dB μ V	50 dB μ V
NOTE: The limit decreases linearly with the logarithm of frequency in the range 0,15 MHz to 0,50 MHz.		

8.4 AC mains power input/output port

This test is applicable for equipment under test, powered by the ac mains.

This test shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

8.4.1 Definition

This test assesses the ability of transmitters, receivers, transceivers and ancillary equipment to limit its internal noise from being present on the ac mains power input ports.

8.4.2 Test method

The test method shall be in accordance with EN 55022 [5].

8.4.3 Limits

The EUT shall meet the Class B limits of EN 55022 [5] shown in table 6.

Table 6 : Limits for conducted RF signals (Class B)

Frequency range	Quasi-peak	Average
0,15 to 0,5 MHz	66 - 56 dB μ V	56 - 46 dB μ V
> 0,5 to 5 MHz	56 dB μ V	46 dB μ V
> 5 to 30 MHz	60 dB μ V	50 dB μ V
NOTE: The limit decreases linearly with the logarithm of frequency in the range 0,15 MHz to 0,50 MHz.		

9 Test methods for immunity tests of transmitters and/or receivers and/or ancillary equipment.

9.1 Test configuration

This subclause defines the requirements for test configurations for tests in the following subclauses and are as follows:

- the measurement shall be made in the operation mode as required in subclause 4.1;
- if the equipment is part of a system, or can be connected to ancillary equipment, then it shall be acceptable to test the equipment connected to the minimum representative configuration of ancillary equipment necessary to exercise the ports;
- for the immunity tests of ancillary equipment, without a separate pass/fail criteria, the receiver, transmitter or transceiver coupled to the ancillary equipment, shall be used to judge whether the ancillary equipment passes or fails;
- the configuration and mode of operation during measurements shall be precisely noted in the test report;
- if the equipment has a large number of ports, then a sufficient number shall be selected to simulate actual operation conditions and to ensure that all the different types of termination are covered;
- ports which in normal operation are connected shall be connected to an ancillary equipment or to a representative piece of cable correctly terminated to simulate the impedance of the ancillary equipment, RF input/output ports shall be terminated by non-radiating loads;
- the tests shall be carried out at a point within the specified normal operating environmental range and at the rated supply voltage for the equipment.

9.2 Radio frequency electromagnetic field (80 to 1 000 MHz)

This test is applicable for all equipment.

This test shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

9.2.1 Definition

This test assesses the ability of transmitters, receivers, transceivers and ancillary equipment to operate as intended in the presence of a radio frequency electromagnetic field disturbance.

9.2.2 Test method

The test method shall be in accordance with ENV 50140 [7] except that the following requirements shall apply:

- the test level shall be 3 V/m amplitude modulated to a depth of 80 % by a sinusoidal audio signal of 400 Hz;

- The stepped frequency increments shall be 10 % of the momentary frequency;
- the test shall be performed over the frequency range 80 to 1 000 MHz with the exception of an exclusion band for transmitters, (see subclause 4.7), and for stand alone receivers or receivers which are part of simplex or duplex transceivers, (see subclause 4.6);
- responses in stand alone receivers or receivers which are part of simplex or duplex transceivers occurring at discrete frequencies which are narrow band responses, are disregarded from the test, (see subclause 4.8);
- the frequencies selected during the test shall be recorded in the test report.

9.2.3 Performance criteria

For transmitters the performance criteria CT (see subclause 6.4) shall apply.

For stand alone receivers or receivers which are part of simplex or duplex transceivers the performance criteria CR (see subclause 6.6) shall apply.

For ancillary equipment the pass/fail criteria supplied by the manufacturer shall apply, unless the ancillary equipment is tested in connection with receivers, transmitters or transceivers in which case the corresponding performance criteria above shall apply.

9.3 Electrostatic discharge

This test is applicable for all equipment.

This test shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

9.3.1 Definition

This test assesses the ability of transmitters, receivers, transceivers and ancillary equipment to operate as intended in the event of an electrostatic discharge.

9.3.2 Test method

The test method shall be in accordance with IEC 1000-4-2.

For transmitters, receivers, transceivers and ancillary equipment the following requirements and evaluation of test results shall apply:

- for contact discharge, the equipment shall pass at ± 2 kV and ± 4 kV;
- for air discharge, it shall pass at ± 2 kV, and then ± 4 kV; and finally ± 8 kV (see IEC 1000-4-2 [8]);
- electrostatic discharges shall be applied to all exposed surfaces of the EUT except:
 - the centre pin of shielded RF connectors (IEC 1000-4-2 [8]),
 - where the user documentation specifically indicates a requirement for appropriate protective measures (IEC 1000-4-2 [8]).

9.3.3 Performance criteria

For transmitters the performance criteria TT (see subclause 6.5) shall apply.

For stand alone receivers or receivers which are part of simplex or duplex transceivers the performance criteria TR (see subclause 6.7) shall apply.

For ancillary equipment the pass/fail criteria supplied by the manufacturer shall apply, unless the ancillary equipment is tested in connection with receivers, transmitters or transceivers in which case the corresponding performance criteria above shall apply.

9.4 Fast transients common mode

This test is applicable for ac powered equipment.

This test shall be performed on ac mains power input ports.

This test shall be performed on signal ports, control ports and dc power input ports if the cables may be longer than three (3) m.

Where this test is not carried out on any ports because the manufacturer declares that it is not intended to be used with cables longer than two (2) m (mobile and ancillary equipment) or one (1) m (base station and fixed ancillary), a list of ports which were not tested shall be included in the test report.

This test shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

9.4.1 Definition

This test assesses the ability of transmitters, receivers, transceivers and ancillary equipment to operate as intended in the event of fast transients present on one of the input/output ports.

9.4.2 Test method

The test method shall be in accordance with IEC 1000-4-4 [9] except that the following requirements shall apply.

For transmitters, receivers, transceivers and ancillary equipment, which have cables longer than three (3) m, or are connected to the ac mains:

- the test level for signal and control ports shall be severity level 2 corresponding to 0,5 kV open circuit voltage as given in paragraph 5 of IEC 1000-4-4 [9];
- the test level for dc power input ports shall be severity level 2 corresponding to 1 kV open circuit voltage as given in paragraph 5 of IEC 1000-4-4 [9];
- the test level for ac mains power input/output ports shall be severity level 3 corresponding to 2 kV open circuit voltage as given in the table paragraph 5 of IEC 1000-4-4 [9];

For ac and dc power input/output ports the transients shall be applied (in parallel) to all the wires in the cable with reference to the cabinet reference ground, i.e. line-to-ground, (true common mode), with a source impedance of 50Ω.

9.4.3 Performance criteria

For transmitters the performance criteria TT (see subclause 6.5) shall apply.

For stand alone receivers or receivers which are part of simplex or duplex transceivers the performance criteria TR (see subclause 6.7) shall apply.

For ancillary equipment the pass/fail criteria supplied by the manufacturer shall apply, unless the ancillary equipment is tested in connection with receivers, transmitters or transceivers in which case the corresponding performance criteria shall apply.

9.5 RF common mode, 0,15 MHz to 80 MHz (current clamp injection)

This test is applicable for ac mains powered, vehicular, and ancillary equipment.

This test shall be performed on signal, control and dc power input/output ports of mobile and ancillary equipment, which may have cables longer than two (2) m.

This test shall be performed on signal, control, dc power and ac mains power input/output ports of ac powered and fixed ancillary equipment, which may have cables longer than one (1) m.

Where this test is not carried out on any ports because the manufacturer declares that it is not intended to be used with cables longer than two (2) m (mobile and ancillary equipment) or one (1) m (ac powered and fixed ancillary equipment), a list of ports which were not tested for this reason shall be included in the test report.

This test shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

9.5.1 Definition

This test assesses the ability of transmitters, receivers, transceivers and ancillary equipment to operate as intended in the presence of a radio frequency electromagnetic disturbance on the input/output ports.

9.5.2 Test method and level

The test method shall be the clamp injection method in accordance with ENV 50141 [10] except that the following requirements shall apply:

- the test signal shall be amplitude modulated to a depth of 80 % by a sinusoidal audio signal of 400 Hz;
- the stepped frequency increments shall be 500 kHz in the frequency range 150 kHz to 5 MHz and 10 % frequency increment of the momentary frequency in the frequency range 5 MHz to 80 MHz;
- the test level shall be severity level 2 as given in table 1 of ENV 50141 [10] corresponding to 3 V rms;
- no intrusive or direct connection shall be made to any of the lines of any input/output port, therefore the clamp injection method shall be used;
- the test shall be performed over the frequency range 150 kHz to 80 MHz with the exception of an exclusion band for transmitters, subclause 4.7, and for stand alone receivers or receivers which are part of simplex or duplex transceivers (see subclause 4.6);
- responses in stand alone receivers or receivers which are part of simplex or duplex transceivers occurring at discrete frequencies which are narrow band responses, are disregarded from the test (see subclause 4.8);
- the frequencies selected during the test shall be recorded in the test report.

9.5.3 Performance criteria

For transmitters the performance criteria CT (see subclause 6.4) shall apply.

For stand alone receivers or receivers which are part of simplex or duplex transceivers the performance criteria CR (see subclause 6.6) shall apply.

For ancillary equipment the pass/fail criteria supplied by the manufacturer shall apply, unless the ancillary equipment is tested in connection with receivers, transmitters or transceivers in which case the corresponding performance criteria above shall apply.

9.6 Transients and surges, vehicular environment

These tests are applicable to mobile and ancillary equipment intended for use in a vehicular environment.

These tests shall be performed on 12 V and 24 V dc power input ports of mobile and ancillary equipment, intended for vehicular use.

These tests shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

9.6.1 Definition

These tests assess the ability of transmitters, receivers, transceivers and ancillary equipment to operate as intended in the event of transients and surges present on the dc power input ports in a vehicular environment.

9.6.2 Test method and level

The test method shall be in accordance with ISO 7637 [4] Part 1 for 12 V dc powered equipment and ISO 7637 [4] Part 2 for 24 V dc powered equipment.

1) The following requirements shall apply for 12 V dc powered equipment:

a) where the manufacturer in his installation documentation requires the EUT to have a direct connection to the 12 V main vehicle battery the following requirements in accordance with ISO 7637 [4] Part 1 shall apply:

- pulse 3a and 3b, level II, with the test time reduced to 5 minutes for each;
- pulse 4, level II, 5 pulses, with the characteristics as follows:
 - $V_s - 5\text{ V}$, $V_a - 2,5\text{ V}$, $t_6 - 25\text{ ms}$, $t_8 - 5\text{ s}$, $t_f - 5\text{ ms}$.

b) where the manufacturer does not require the EUT to have a direct connection to the 12 V main vehicle battery, the following pulses apply, in addition to the pulses in 1) a):

- pulse 1, level II $t_1 - 2,5\text{ s}$, 10 pulses.
- pulse 2, level II $t_1 - 2,5\text{ s}$, 10 pulses.
- pulse 7, level II 5 pulses.

Where the manufacturer declares that the EUT requires a direct connection to the vehicle battery, and therefore the tests in accordance with 1) b) are not carried out, this shall be stated in the test report.

2) The following requirements shall apply for 24 V dc powered equipment:

a) where the manufacturer in his installation documentation requires the EUT to have a direct connection to the 24 V main vehicle battery the following requirements in accordance with ISO 7637 [4] Part 2 shall apply:

- pulse 3a and 3b, level II, with the test time reduced to 5 minutes for each;
- pulse 4, level II, 5 pulses, with the characteristics as follows:
 - $V_s - 10\text{ V}$, $V_a - 5,0\text{ V}$, $t_6 - 25\text{ ms}$, $t_8 - 5\text{ s}$, $t_f - 5\text{ ms}$.

The test for pulse 4 shall be carried out as specified in ISO 7637 [4] Part 1.

b) where the manufacturer does not require the EUT to have a direct connection to the 24 V main vehicle battery, the following pulses apply, in addition to the pulses in 2) a):

-	pulse 1a, level II	t1 - 2,5 s,	Ri - 25Ω	10 pulses.
-	pulse 1b, level II	t1 - 2,5 s,	Ri - 100 Ω	10 pulses.
-	pulse 2, level II	t1 - 2,5 s,		10 pulses.

Where the manufacturer declares that the EUT requires a direct connection to the vehicle battery, and therefore the tests in accordance with 2) b) are not carried out, this shall be stated in the test report.

For radio and ancillary equipment designed to operate at both dc power voltages both requirement 1) and 2) shall apply.

For radio equipment designed to operate at 12 V dc power supply, but operating from a 24 V dc power adapter ancillary, then the radio equipment shall comply with the requirements in 1) and the configuration of the radio equipment and the power adapter shall comply with the requirements of 2).

9.6.3 Performance criteria

For transmitters, pulses 3a and 3b, the performance criteria CT (see subclause 6.4) shall apply. For pulses 1, 1a, 1b, 2, 4 and 7 the performance criteria TT (see subclause 6.5) shall apply, with the exception that the link need not have been maintained during exposure and may have to be re-established.

For stand alone receivers or receivers which are part of transceivers, pulses 3a and 3b the performance criteria CR (see subclause 6.6) shall apply. For pulses 1, 1a, 1b, 2, 4 and 7 the performance criteria TR (see subclause 6.7) shall apply, with the exception that the link need not have been maintained during exposure and may have to be re-established.

For ancillary equipment the pass/fail criteria supplied by the manufacturer shall apply, unless the ancillary equipment is tested in connection with receivers, transmitters or transceivers in which case the corresponding performance criteria above shall apply.

9.7 Voltage dips and interruptions

These tests are applicable for ac powered equipment, including ancillary equipment.

These tests shall be performed on ac mains power input ports.

These tests shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

9.7.1 Definition

These tests assess the ability of transmitters, receivers, transceivers and ancillary equipment to operate as intended in the event of voltage dips and interruptions present on the ac mains power input ports.

9.7.2 Test method

The following requirements shall apply.

The test method shall be in accordance with IEC 1000-4-11 [11].

The test levels shall be:

- a voltage dip corresponding to a reduction of the supply voltage of 30 % for 10 ms;
- a voltage dip corresponding to a reduction of the supply voltage of 60 % for 100 ms;
- a voltage interruption corresponding to a reduction of the supply voltage of > 95 % for 5 000 ms.

9.7.3 Performance criteria

For a voltage dip corresponding to a reduction of the supply voltage of 30 % for 10 ms the following performance criteria apply:

- for transmitters the performance criteria CT (see subclause 6.4);
- for stand alone receivers or receivers which are part of simplex or duplex transceivers the performance criteria CR (see subclause 6.6);
- for ancillary equipment the pass/fail criteria supplied by the manufacturer shall apply, unless the ancillary equipment is tested in connection with receivers, transmitters or transceivers in which case the corresponding performance criteria above shall apply.

For a voltage dip corresponding to a reduction of the supply voltage of 60 % for 100 ms the following performance criteria apply:

- for transmitters the performance criteria TT (see subclause 6.5);
- for stand alone receivers or receivers which are part of simplex or duplex transceivers the performance criteria TR (see subclause 6.7);
- for ancillary equipment the pass/fail criteria supplied by the manufacturer shall apply, unless the ancillary equipment is tested in connection with receivers, transmitters or transceivers in which case the corresponding performance criteria above shall apply.

For a voltage dip corresponding to a reduction of the supply voltage of 60 % for 100 ms and/or a voltage interruption corresponding to a reduction of the supply voltage of > 95 % for 5 000 ms the following performance criteria apply:

- in the case where the equipment is fitted with or connected to a battery back-up the performance criteria TT (see subclause 6.5) or TR (see subclause 6.7) apply as appropriate;
- in the case where the equipment is powered solely from the ac mains supply (without the use of a parallel battery back-up) the communications link need not be maintained and may have to be re-established and volatile user data may have been lost.

In the event of loss of the communications link or in the event of loss of user data, this fact shall be recorded in the test report, the product description and the user documentation.

9.8 Transients common and differential mode

These tests are applicable for ac powered and fixed ancillary equipment.

These tests shall be performed on ac mains power input ports.

These tests shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

9.8.1 Definition

These tests assess the ability of transmitters, receivers, transceivers and ancillary equipment to operate as intended in the event of transients present on the ac mains power input ports.

9.8.2 Test method and level

The following requirements and evaluation of test results shall apply.

The test method shall be in accordance with ENV 50142 [12] as follows:

- the test level shall be severity level 2 corresponding to 1 kV open circuit voltage for line-to-ground and severity level 2 corresponding to 0,5 kV open circuit voltage for line-to-line;
- the transients shall be applied (in parallel) to all the wires in the cable with reference to the cabinet reference ground, for line to ground tests, i.e. true common mode, with a series resistance of 10 Ω .

9.8.3 Performance criteria

For transmitters the performance criteria TT (see subclause 6.5) shall apply.

For stand alone receivers or receivers which are part of simplex or duplex transceivers the performance criteria TR (see subclause 6.7) shall apply.

For ancillary equipment the pass/fail criteria supplied by the manufacturer shall apply, unless the ancillary equipment is tested in connection with receivers, transmitters or transceivers in which case the corresponding performance criteria above shall apply.

Annex A (normative): EUT test configuration requirements

A.1 General

This annex defines the methods of stimulating the EUT when carrying out the necessary EMC tests given in this ETS, in recognition of the unusual nature of radio microphones, as compared with the generality of radio products.

Radio microphones vary enormously in their sensitivity and the directivity of their microphones.

In testing radio microphones, it should be borne in mind that many products employ companding techniques.

In the event of difficulty, or uncertainty about the characteristics of the sample submitted for evaluation, discussion with the manufacturer is encouraged.

A.2 Audio excitation

As part of the EMC test sequence given in this ETS it is necessary to provide an audio excitation signal to the microphone transducer. This may be achieved in at least two ways, as follows:

- 1) by means of an electro-acoustic resonator, (in order to avoid distortion of the calibrated field, this shall be placed outside the physical area of calibration, and be non-metallic); or
- 2) by means of an acoustic tube, (this may be rigid or flexible, but shall have a "hard" wall, be of non-conducting material, and be of constant inner diameter throughout its length).

The driver transducer shall be large enough, and excited strongly enough, to be able to deliver sufficient sound pressure at the microphone to fully excite the EUT's modulator. Overdrive shall be avoided.

The driver transducer shall be placed well away from the EUT's microphone, (because it will ordinarily be a moving coil magnetic type), in order to avoid inter-transducer magnetic coupling, and in order to avoid distortion of the electro-magnetic field.

Coupling to the driver transducer, and to the EUT's microphone transducer, may be by means of funnels or other appropriate means. The attachments shall be fixed and firm throughout the test sequence.

When the transducer is coupled to the EUT by means of an acoustic tube, bends in the tube shall be avoided or minimized. Any bends in the tube shall always have a radius that is large in relation to the inner diameter of the tube. Standing waves in the tube may be overcome by lightly packed cotton wool damping pads placed at 150 mm intervals along the length of the tube. It is recommended that the driver transducer is located inside the test chamber, thus minimizing the length of the tube.

NOTE: In trials of this test method a tube length of 1m has been successfully used. The tube was 12,5 mm bore plastic reinforced water hose. The driver transducer was a 75 mm car radio speaker, with a large ferrite magnet, capable of cone movement exceeding 10 mm peak-to-peak. The driver was coupled into the pipe by means of a domestic plastic funnel.

History

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