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**Electromagnetic compatibility requirements for  
radio telecommunication equipment**

Recommendation ITU-T K.136

ITU-T





# Recommendation ITU-T K.136

## Electromagnetic compatibility requirements for radio telecommunication equipment

### Summary

Recommendation ITU-T K.136 specifies the electromagnetic compatibility (EMC) requirements and the test method for radio telecommunication equipment and associated ancillary equipment.

### History

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## Recommendation ITU-T K.136

### Electromagnetic compatibility requirements for radio telecommunication equipment

#### 1 Scope

This Recommendation specifies the general requirements of electromagnetic compatibility (EMC) and test methods for radio telecommunication and associated ancillary equipment. Radio equipment includes e.g., mobile access network equipment such as base stations, fixed radio links equipment such as microwave relay, fixed-satellite service, radio navigation-satellite services, short-range devices, mobile broadband access devices, mobile-satellite service, and wireless access point devices. Specific product Recommendations, e.g., [b-ITU-T K.114] and [b-ITU-T K.116], take precedence over this Recommendation.

The working frequencies of radio equipment could be from 9 kHz to 400 GHz.

This Recommendation describes the common testing operational conditions and performance criteria.

This Recommendation describes specific testing levels to be applied to radio equipment in various environments. The EMC requirements have been specified to ensure an adequate level of compatibility for equipment intended to be used in the environments mentioned above. The levels, however, do not cover extreme cases which may occur in any location but with low probability of occurrence.

#### 2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

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- [ITU-T K.34] Recommendation ITU-T K.34 (2003), *Classification of electromagnetic environmental conditions for telecommunication equipment – Basic EMC Recommendation.*
- [ITU-T K.38] Recommendation ITU-T K.38 (1996), *Radiated emission test procedure for physically large systems.*
- [IEC 61000-3-2] IEC 61000-3-2 (2018), *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current  $\leq 16$  A per phase).*
- [IEC 61000-3-3] IEC 61000-3-3 (2013), A1 (2017), *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current  $\leq 16$  A per phase and not subject to conditional connection.*

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- [IEC 61000-4-2] IEC 61000-4-2 (2008), *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test.*
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- [IEC CISPR 16-1-2] IEC CISPR 16-1-2 (2014), AMD1 (2017), *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Coupling devices for conducted disturbance measurements.*
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- [IEC CISPR 32] IEC CISPR 32 (2015), *Electromagnetic compatibility of multimedia equipment – Emission requirements.*
- [IEC CISPR 35] IEC CISPR 35 (2016), *Electromagnetic compatibility of multimedia equipment – Immunity requirements.*
- [ISO/IEC 17025] ISO/IEC 17025 (2017), *General requirements for the competence of testing and calibration laboratories.*

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

**3.1.1 AC mains power port** [IEC CISPR 35]: Port used to connect to the AC mains supply network.

**3.1.2 analogue/digital data port** [IEC CISPR 35]: Signal/control port, antenna port, wired network port, or optical fibre port with metallic shielding and/or metallic strain relief member(s).

**3.1.3 antenna port** [b-ETSI EN 301 489-1]: Port, for connection of an antenna used for intentional transmission and/or reception of radiated RF energy.

**3.1.4 arrangement** [IEC CISPR 35]: Physical layout and orientation of all the parts of the EUT, AE and any associated cabling, located within the test area.

**3.1.5 associated equipment** [IEC CISPR 35]: Equipment needed to exercise and/or monitor the operation of the EUT.

**3.1.6 audio equipment** [IEC CISPR 35]: Equipment which has a primary function of either (or a combination of) generation, input, storage, play, retrieval, transmission, reception, amplification, processing, switching or control of audio signals.

**3.1.7 base station equipment** [b-ETSI EN 301 489-1]: Radio and/or ancillary equipment intended for operation at a fixed location and powered directly or indirectly (e.g., via an AC/DC converter or power supply) by the AC mains network, or an extended local DC mains network.

**3.1.8 common mode impedance** [IEC CISPR 35]: Asymmetrical mode impedance between a cable attached to a port and the Reference Ground Plane (RGP).

**3.1.9 configuration** [IEC CISPR 35]: Operational conditions of the EUT and AE, consisting of the set of hardware elements selected to comprise the EUT and AE, the mode of operation used to exercise the EUT and arrangement of the EUT and AE.

**3.1.10 converted common mode current** [IEC CISPR 35]: Asymmetrical mode current converted from differential mode current by the unbalance of an attached cable and/or network.

**3.1.11 DC network power port** [IEC CISPR 35]: Port, not powered by a dedicated AC/DC power converter and not supporting communication, that connects to a DC supply network.

NOTE 1 – Equipment with a DC power port which is powered by a dedicated AC/DC power converter is defined as AC mains powered equipment.

NOTE 2 – DC power ports supporting communication are considered to be wired network ports, for example Ethernet ports which include power over Ethernet (POE).

**3.1.12 enclosure port** [IEC CISPR 35]: Physical boundary of the EUT through which electromagnetic fields may radiate or may enter.

**3.1.13 equipment Under Test** [IEC CISPR 35]: Equipment being evaluated for compliance with the requirements of this document.

**3.1.14 formal measurement** [IEC CISPR 35]: Measurement used to determine compliance.

NOTE – This is often the final measurement performed. It may be carried out following a prescan measurement. It is the measurement recorded in the test report.

**3.1.15 function** [IEC CISPR 35]: Operation carried out by an equipment.

NOTE – Functions are related to basic technologies incorporated in the equipment such as: displaying, recording, processing, controlling, reproducing, transmitting, or receiving single medium or multimedia content. Where relevant the content may be data, audio or video, either individually or in combination.

**3.1.16 highest internal frequency** [IEC CISPR 35]: Highest fundamental frequency generated or used within the EUT, or highest frequency at which it operates.

**3.1.17 information technology equipment** [IEC CISPR 35]: Equipment having a primary function of either (or a combination of) entry, storage, display, retrieval, transmission, processing, switching, or control of data and/or telecommunication messages and which may be equipped with one or more ports typically for information transfer.

**3.1.18 integral antenna** [IEC CISPR 35]: Antenna designed for permanent connection to the equipment and considered part of the enclosure port.

NOTE – An integral antenna may be fitted internally or externally.

**3.1.19 mobile equipment** [b-ETSI EN 301 489-1]: Receiver, transmitter or transmitter/receiver (transceiver) intended for installation and use in a vehicle, and powered by the main battery of the vehicle.

**3.1.20 mode of operation** [IEC CISPR 35]: Set of operational states of all functions of an EUT during a test or measurement.

**3.1.21 multi-radio equipment** [b-ETSI EN 301 489-1]: Radio equipment containing two or more radio transmitters and/or receivers using different technologies that may operate simultaneously.

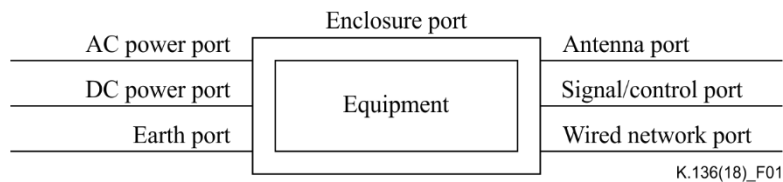
**3.1.22 multi-standard-radio** [b-ETSI EN 301 489-1]: Radio equipment with ability of its receiver and transmitter to process two or more carriers in common active RF components simultaneously in

a declared RF bandwidth, where at least one carrier is of a different radio access technology than the other carrier(s).

**3.1.23 occupied bandwidth** [b-ITU Radio Regs]: The width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage  $b/2$  of the total mean power of a given emission. Unless otherwise specified in an ITU-R Recommendation for the appropriate class of emission, the value of  $b/2$  should be taken as 0.5%.

**3.1.24 port** [IEC CISPR 35]: Physical interface through which electromagnetic energy enters or leaves the EUT.

NOTE – See Figure 1.



**Figure 1 – Examples of ports**

**3.1.25 portable equipment** [b-ETSI EN 301 489-1]: Radio and/or ancillary equipment intended for portable (e.g., handheld) operation, powered by its own integral battery.

**3.1.26 primary function** [IEC CISPR 35]: Any function of an equipment considered essential for the user or for the majority of users.

**3.1.27 primary protection** [IEC CISPR 35]: Means by which the majority of surge stress is prevented from propagating beyond a designated location (preferably the building entrance point).

**3.1.28 primary protector** [IEC CISPR 35]: Surge protection device used for the primary protection of analogue/digital ports that may connect to cables that leave the building structure.

**3.1.29 signal/control port** [IEC CISPR 35]: Port intended for the interconnection of components of an EUT, or between an EUT and AE and used in accordance with relevant functional specifications (for example for the maximum length of cable connected to it).

**3.1.30 wired network port** [IEC CISPR 35]: Port for the connection of voice, data and signalling transfers intended to interconnect widely dispersed systems by direct connection to a single-user or multi-user communication network.

NOTE 1 – Examples of these include CATV, PSTN, ISDN, xDSL, LAN and similar networks.

NOTE 2 – These ports may support screened or unshielded.

## 3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

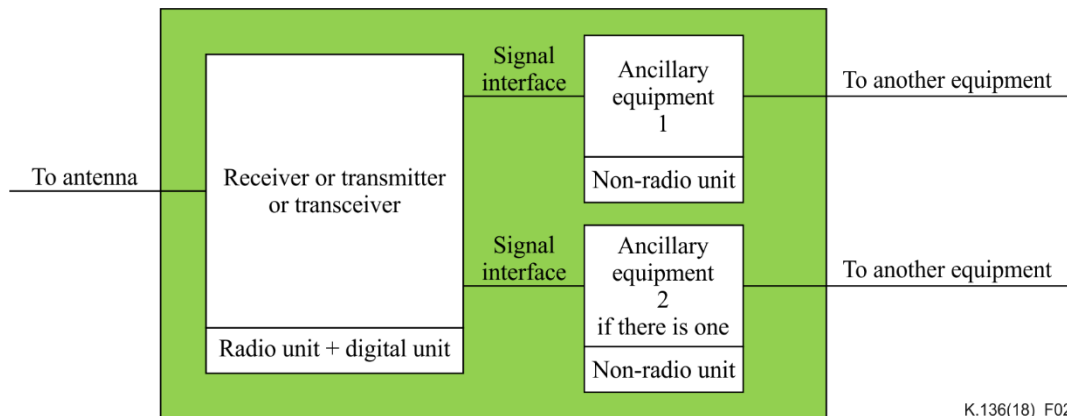
**3.2.1 ancillary equipment:** This is an electrical or electronic equipment, that is intended to be used with a receiver or transmitter and that can be in the same enclosure (see Figure 2) or in a separate enclosure (see Figure 3) of the radio transceiver.

NOTE 1 – It is considered as an ancillary equipment if:

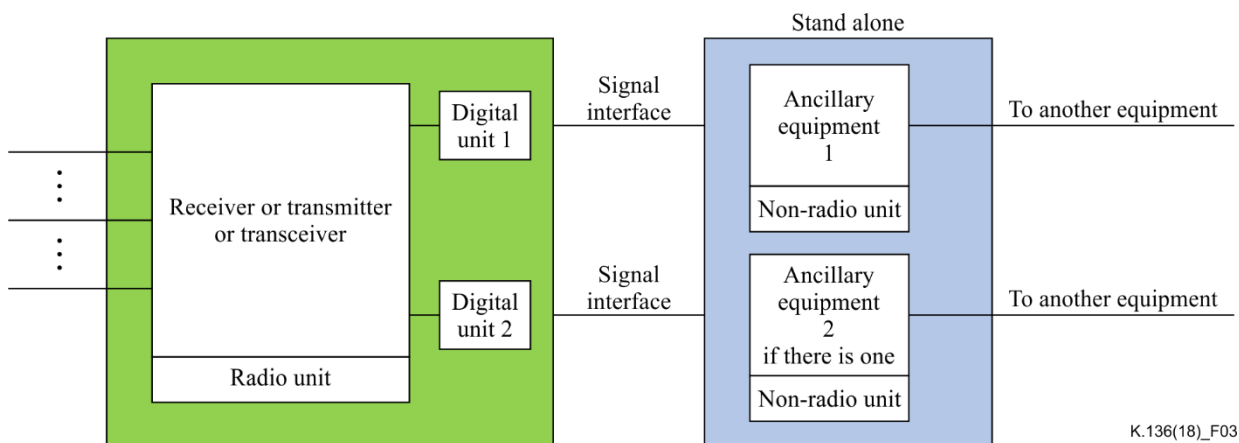
- the equipment is intended for use with a receiver or transmitter to provide additional operational and/or control features to the radio equipment, (e.g., to extend control to another position or location); and
- the equipment cannot be used to provide user functions independently of a receiver or transmitter; and

- the receiver or transmitter, 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).

NOTE 2 – This is a modified version of the definition given [b-ETSI EN 301 489-1].



**Figure 2 – Ancillary equipment**



**Figure 3 – Standalone ancillary equipment**

**3.2.2 combined Radio equipment:** Equipment consisting of two or more products where at least one of which is radio communication equipment and at least one of which is non-radio equipment.

NOTE – This is a modified version of the definition given in [b-ETSI EN 301 489-1].

**3.2.3 customer premises environment:** A customer premises environment is a facility in the residential and commercial building, there is no guarantee for good protection, earthing and bonding, and this environment is more abominable than the telecommunication centre, including but not limited to:

- facility in the corridor;
- facility in the weak power wells;
- facility in the distribution room;
- facility in the basement, etc.;
- facility in the lobby of buildings.

The electromagnetic environmental conditions for customer premises environments are described in clause 6.1 of [ITU-T K.34].

NOTE – This is a modified version of the definition given in [b-ITU-T K.114].

**3.2.4 DC power port:** Port used to connect to the DC supply network.

**3.2.5 outside environment (outdoor location):** An environment where equipment is exposed to the atmosphere and is more abominable than the customer premises environment, including but not limited to:

- facility on the streets side;
- facility on the roof of buildings;
- facility on the outside wall of buildings;
- facility on the pole, etc.;
- facility on the towers.

The electromagnetic environmental conditions for outdoor environments are described in clause 7.1 of [ITU-T K.34].

NOTE – This is a modified version of the definition given in [b-ITU-T K.114].

**3.2.6 radio equipment:** An electrical or electronic product, which primary function is to intentionally transmits and/or receives radio waves for the purpose of radio communication.

NOTE – This is a modified version of the definition given in [b-ETSI EN 301 489-1].

**3.2.7 radio module:** Piece of radio equipment that can be added to a product to allow radio communication.

**3.2.8 repeater:** Device with two RF ports, both of which are intended to be connected to antennas, capable of receiving, amplifying and transmitting simultaneously in one direction a signal in a base station system (BSS) transmit band and in the other direction a signal in the corresponding BSS receive band.

**3.2.9 telecommunication centre:** A facility which is managed and operated exclusively by the telecom operator. This environment is more normative than the customer premises and the outside environment is sufficient to guarantee good protection, earthing and bonding, including but not limited to:

- facility in the centre office;
- facility in the data centre.

The electromagnetic environmental conditions for telecommunication centres are described in clause 6.1 of [ITU-T K.34].

NOTE – This is a modified version of the definition given in [b-ITU-T K.114].

**3.2.10 throughput:** Number of payload bits successfully received per second for a reference measurement channel in a specified reference condition.

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AAS	Adaptive Antenna System
AC	Alternating Current
AM	Amplitude Modulation
AMN	Artificial Mains Network
BER	Bit Error Ratio
BLER	Block Error Ratio

BSS	Base Station System
BTS	Base Station
CDN	Coupling Decoupling Network
CRT	Cathode Ray Tube
DC	Direct Current
e.i.r.p.	Equivalent Isotropically Radiated Power
e.r.p.	Effective Radiated Power
EMC	Electromagnetic Compatibility
EUT	Equipment Under Test
FER	Frame Erasure Ratio
ISN	Impedance Stabilisation Network
MSR	Multi-Standard Radio
PD	Powered Device
PoE	Power over Ethernet
PSE	Power Sourcing Equipment
QoS	Quality of Service
RF	Radio Frequency

## 5 Conventions

None.

## 6 Test methods and limits

Emission and immunity requirements are defined in the following clauses.

### 6.1 Emission requirements

The general requirements for test methods and limits apply, according to [IEC CISPR 32]. Tables A.1 and A.2 apply to equipment intended for use in telecommunication centres and customer premises, and outdoor plants, respectively.

Radiated emission measurements should be performed at higher frequency bands; the following table shows the necessary highest frequency up to which radiated emission tests should be performed.

**Table 1 – Required highest frequency for radiated emission test**

Highest internal frequency( $F_x$ )	Measured up to highest frequency
$F_x \leq 108$ MHz	1 GHz
$108$ MHz $< F_x \leq 500$ MHz	2 GHz

**Table 1 – Required highest frequency for radiated emission test**

Highest internal frequency( $F_x$ )	Measured up to highest frequency
$500 \text{ MHz} < F_x \leq 1 \text{ GHz}$	5 GHz
$F_x > 1 \text{ GHz}$	$5 \times F_x$ up to a maximum of 40 GHz
NOTE – $F_x$ : highest fundamental frequency generated or used within the equipment under test (EUT) or highest frequency at which it operates.	

Conducted emission measurements at power input and/or output ports shall be performed using the artificial mains network (AMN) defined in [IEC CISPR 16-1-2] and test methods defined in [IEC CISPR 32]. The test method for alternating current (AC) mains port defined in [IEC CISPR 32] applies to the direct current (DC) power port.

Conducted emission measurements on wired-network ports shall be performed using the impedance stabilization network (ISN) defined in [IEC CISPR 16-1-2] and test methods defined in [IEC CISPR 32].

Cable arrangement and test setups shall be according to [IEC CISPR 32].

Measurement instrumentation uncertainty shall be determined according to [IEC CISPR 16-4-2] as defined in [IEC CISPR 32].

**6.1.1 Emission of radio transmitter functions:** Emission of radio carrier and its spurious responses generated by the transmitter functions of the EUT shall be in accordance with applicable ITU-R Recommendations.

**6.1.2 Radiated emissions on ancillary equipment:** Radiated emission tests on standalone ancillary equipment (see Figure 3) shall be performed according to [IEC CISPR 32].

Radiated emission tests on ancillary equipment incorporated in the same enclosure of radio transceiver (see Figure 2) shall be performed according to [IEC CISPR 32] if the radio function can be disabled. Instead, if the radio function cannot be disabled, the radiated emissions are measured according to the relevant ITU-R Recommendations.

**6.1.3 Power over Ethernet (PoE) port:** The PoE port should be considered to be a wired-network port to conduct the conducted emission measurements as described in Annex C.

**6.1.4 Current harmonics:** The appropriate requirements of [IEC 61000-3-2] for harmonic current emissions apply to any equipment covered by the scope of this Recommendation with an input current up to and including 16 A per phase. For equipment with an input current greater than 16 A and less than 75 A per phase, [IEC 61000-3-12] applies.

**6.1.5 Flickers:** The appropriate requirements of [IEC 61000-3-3] for voltage fluctuations and flicker apply for equipment covered under the scope of this Recommendation with an input current up to and including 16 A per phase. For equipment with an input current greater than 16 A and less than 75 A per phase, [IEC 61000-3-11] applies.

## 6.2 Immunity requirements

The immunity requirements for telecommunication and radio equipment are given on a port by port basis.

Test levels are defined in Tables B.1, B.2 and B.3. Test levels have been defined taking into account the electromagnetic environment referred to in [ITU-T K.34]. The general test methods are those in the reference basic standards as defined in Tables B.1 to B.3.

Conducted immunity tests shall be applied to each port at a time.

Conducted immunity testing shall be performed on power input and output ports and on signal ports.

Intra-system cables and ports shall not be tested. The manufacturer is responsible for ensuring that no degradation in system immunity results due to intra-system cabling occurrences (where the manufacturer controls both ends).

For surge tests, when defined, it is allowed to test equipment with the primary protection installed. The test condition should be added in the test report.

If the specified maximum length of the connected cables is less than 3 m, no conducted immunity tests are required. For surge tests on indoor signal lines, no test is required if the specified cable's maximum length is less than 10 m.

One signal port of each type on the equipment shall be tested. If, in normal installation practice, multi-pair cables (e.g., 64 x balanced pairs) and/or composite cables (e.g., a combination of fibre and copper) are used, they are to be tested as a single cable. Cables bundled for aesthetic or routing purposes are to be tested individually.

For multi-pair cables where a multi-pair coupling decoupling network (CDN) does not exist, the test shall be applied to a single pair using an appropriate CDN, the remaining pairs should be considered to have been tested indirectly.

During the surge test, the EUT and all ports (other than the one connected to the generator) shall comply with the given compliance criteria. After the surge has been applied, the generator shall be disconnected from the port and the port checked against the compliance criteria. The compliance criteria shall contain functional aspects.

During immunity testing using continuous phenomena, the appropriate exclusion band shall be applied to radio equipment.

Immunity test arrangements shall be in accordance with [IEC CISPR 35] where applicable.

## **7 General operational conditions and test configuration**

### **7.1 General conditions**

The equipment shall be tested under normal test conditions according to relevant product and basic standards or to the information provided with the equipment.

Tests shall be performed within the manufacturers declared range of humidity, temperature and supply voltage.

EUT configuration and mode of operation shall represent the intended use.

The test conditions, EUT configuration and mode of operation shall be recorded in the test report.

### **7.2 General configurations**

The general configuration refers to [b-ETSI EN 301 489-1].

Adequate measures shall be taken to avoid impact on the emission tests due to disturbances produced by auxiliary equipment.

Adequate measures shall be taken to avoid disturbances on the auxiliary equipment and wanted signal sources during immunity tests.



**7.2.1 Arrangements for test signals at the input of transmitters:** The transmitter shall be modulated with normal test modulation, by an internal or external signal source capable of delivering the normal test modulation as specified in the product specifications or by manufacturer documentation.

**7.2.2 Arrangements for test signals at the RF output of transmitters:** For transmitters with an integral antenna, the wanted radio frequency (RF) output signal to establish a communication link shall be delivered from the EUT to an antenna located within the test environment. This antenna shall be connected to the external RF signal source by a coaxial cable.

For transmitters with an antenna connector, the wanted RF output signal to establish a communication link shall be delivered from the antenna connector to the external measuring equipment by a shielded transmission line (e.g., coaxial cable). Adequate measures shall be taken to minimize the effect of unwanted common mode currents on the external conductor of the transmission line at the point of entry to the transmitter.

The level of the wanted RF output signal in transmit mode of operation shall be set to the maximum rated RF power for the EUT, modulated with the normal test modulation.

**7.2.3 Arrangements for test signals at the RF input of receivers:** The signal source shall be modulated with normal test modulation as specified in product specifications or by the manufacturer's documentation.

For receivers with an integral antenna, the wanted RF input signal to establish a communication link shall be provided to the EUT with an antenna located within the test environment. This antenna shall be connected to the external RF signal source by a coaxial cable.

For receivers with an antenna connector, the wanted RF input signal to establish a communication link shall be provided to the antenna connector of the EUT with a shielded transmission line (e.g., coaxial cable). The transmission line shall be connected to the external RF signal source. Adequate measures shall be taken to minimize the effect of unwanted common mode currents on the external conductor of the shielded transmission line at the point of entry to the receiver.

The level of the wanted RF input signal shall be set to be approximately 40 dB above the minimum level necessary to achieve a receiver performance which meets the relevant specified performance criteria.

NOTE – This level of the wanted RF input signal is expected to represent a normal operation signal level and should be sufficient to avoid the broadband noise from the power amplifiers generating the EM disturbance from influencing the measurement.

**7.2.4 Arrangements for test signals at the output of receivers:** For receivers with an analogue speech output, the audio output from the acoustic transducer should be coupled via an electrically non-conductive acoustic tube to an external audio distortion meter or other appropriate measuring equipment. Where it is not practical to use an electrically non-conductive acoustic tube, then other means of connecting the receiver output signal to the external audio distortion meter or other measuring equipment shall be provided and recorded in the test report.

For receivers with a non-speech output, the output signal shall be coupled via an electrically non-conductive means to the external measuring equipment (e.g., a camera to read a display). If the receiver has an output connector or port providing the wanted output signal, then this port shall be used via a cable, consistent with the standard cable used in normal operation, connected to the external measuring equipment outside the test environment.

**7.2.5 Arrangements for testing transmitter and receiver together (as a system):** Transmitters and receivers may be tested for immunity as a system when combined as a transceiver. In this case the transceiver or transmitter and receiver shall be located inside the test environment and shall be exposed simultaneously to the immunity test signals.

For transceivers or transmitters and receivers operating at the same frequency, the wanted output signal of the transmitter may be used via a suitable attenuator and applied to the input of the receiver as the wanted input signal.

### 7.3 RF exclusion band

The exclusion bands shall be derived using the methodologies defined in [b-ETSI EN 301 489-1] and detailed in clauses 7.3.1 and 7.3.2.

Whenever an exclusion band is applied, the specific frequency range(s) excluded from assessment shall be detailed in the technical documentation and in the test report.

**7.3.1 Exclusion band for transmitters or the transmitter part of transceivers:** Exclusion bands shall not be applied when measuring transmitters in standby mode.

**7.3.1.1 Channelized equipment:** For channelized equipment, the exclusion band shall extend 250% of the channel width either side of the transmitter centre frequency.

NOTE – Exclusion band of 250% is based on the [ITU Radio Regulations], as the boundary between out-of-band and spurious domain.

**7.3.1.2 Non-channelized equipment:** For non-channelized equipment, the exclusion band shall extend 250% of the occupied bandwidth either side of the transmitter centre frequency.

NOTE – Exclusion band of 250% is based on the [ITU Radio Regulations], as the boundary between out-of-band and spurious domain.

**7.3.2 Exclusion band for receivers or the receiver part of transceivers:** Exclusion bands are not applied when testing emissions of receivers or the receiver part of transceivers.

**7.3.2.1 Channelized equipment:** For channelized equipment, the exclusion band shall be calculated using the following formulae:

For the lower edge for the exclusion band:

$$EXband(lower) = Band_{RX}(lower) - nChW_{RX}$$

and for the upper edge of the exclusion band:

$$EXband(upper) = Band_{RX}(upper) + nChW_{RX}$$

Where  $n$  = number of channel widths required for exclusion band.

For equipment that supports multiple channel widths, the channel width used should be the widest supported by the EUT.

The value of  $n$  shall be 1 if not defined in the product specification.

**7.3.2.2 Non-channelized equipment:** For non-channelized equipment, the exclusion band shall be calculated using the following formula:

For the lower edge for the exclusion band:

$$EXband(lower) = Band_{RX}(lower) - nBW_{RX}$$

and for the upper edge of the exclusion band:

$$EXband(upper) = Band_{RX}(upper) + nBW_{RX}$$

Where  $n$  = multiple of whole bandwidths required to define exclusion band.

Bandwidth of receiver is the occupied bandwidth of the corresponding transmitter signal.

The value of  $n$  shall be 1 if not defined in the product specification.

#### **7.4 Narrowband responses of receivers or receivers which are part of transceivers**

Responses on receivers or the receiver part of transceivers occurring during immunity tests at discrete frequencies which are narrowband responses (spurious responses), are identified by the following method.

If during the test the immunity RF test signal causes non-compliance of the receiver with the specified performance criteria, it is necessary to evaluate whether this non-compliance is due to a narrowband response or a wideband phenomenon. Therefore, the frequency of the test signal is increased by an amount equal to twice the nominal 6 dB bandwidth of the IF filter immediately preceding the demodulator of the receiver, or if appropriate, the bandwidth over which the equipment is intended to operate, as declared by the manufacturer. The test is repeated with the frequency of the test signal decreased by the same amount.

If the receiver is then in either or both frequency offset cases in compliance with the specified performance criteria, the response is considered as a narrowband response.

If the receiver still does not comply with the specified performance criteria, this may be due to the fact that the offset has made the frequency of the unwanted signal correspond to the frequency of another narrowband response. Under these circumstances the procedure is repeated with an increase and decrease of the frequency of the test signal adjusted two and a half times the bandwidth referred to above.

If the receiver still does not comply with the specified performance criteria in either or both frequency offset cases, the phenomena is considered wideband and therefore an EMC problem and the equipment fails the test.

For immunity tests, narrowband responses shall be disregarded.

#### **7.5 Normal test modulation**

For the purpose of EMC tests, the transmitter under test shall be modulated according to the normal test modulation specified in the relevant product specifications or manufacturer documentation

For the purpose of EMC tests, the receiver under test shall be provided with a wanted RF input signal modulated according to the normal test modulation specified in the relevant product specifications or manufacturer documentation.

#### **7.6 Operational conditions**

The earthing of the EUT should be in accordance with that of a normal installation.

The measurement should be made at the nominal voltage of the EUT. If an EUT supports a wide range of supply voltage, then the typical operating voltage, for example 110 V and 230 V, is recommended for the measurement. Equipment with a DC power port powered by a dedicated AC/DC power converter is considered to be an AC mains powered equipment and should be measured with a power converter. Where the power converter is provided by the manufacturer, the converter provided should be used.

Environmental parameters (temperature, humidity and atmospheric pressure) should be limited to the installation conditions of the EUT, and it is not necessary to repeat measurements at more than one set of environmental parameters.

The loading status of the power supply and/or the bit rate of the interface should be representative of the typical use of the EUT. One or more measurements may be repeated to adequately assess the emission or immunity of the EUT. For digital interfaces, it is acceptable to measure at the highest bit rate.

All the ports should be exercised in a manner which is representative of as normal operation as possible. For example the ports are high-speed driven as specified, and the line attenuation is simulated as the actual length as possible.

The exercising signal should be selected to simulate the intended function and the correct operation of the equipment, e.g., data rate, packet length.

Special exercising equipment and/or software may be used with the object of reducing the test time and to simulate traffic conditions, and the actual situation of test should be recorded in the test report.

## **7.7 Test configuration**

The EUT should be configured to the maximum of its emission (worst case) and at the minimum of its immunity based on a representative configuration of real applications when use as intended.

Equipment may provide different functions, all available functions of the EUT should be tested.

For equipment supporting multi-type line cards, and supporting several combination of those line cards to achieve different marketing configurations, for example the GE card, 10 GE card, of optical or electrical interface, for uplink or downlink, then each type of the functional line card should be selected for the test configuration. A combination of the test configuration to cover all the different line cards may be considered to maximize the emission. In principle, every type of line card should be assessed.

Where there are multiple line cards of the same type, the manufacturer should determine whether to load these additional cards, considering:

- a representative configuration;
- reproducibility;
- maximization of the emission levels, for example, when adding additional cards or cables does not significantly affect the emission level (for example varies less than 2 dB), it can be assumed that a maximum has occurred.

This process may also be applied to establishing the number of similar elements (e.g., plugin modules, internal memory) within the EUT.

Where the EUT has more than one analogue/digital data port, ports should be included in the measurement arrangement for conducted emission and conducted immunity as follows:

- if there are multiple same ports on the same card or module type, then it is acceptable to assess one typical port;
- if there are ports of the same type on different card or module types, then it is acceptable to assess one typical port on each card or module type.

The test report should include the type of ports assessed.

## **7.8 Test conditions for equipment with a special port**

Test conditions for POE port should be in accordance with Annex C.

# **8 Performance assessment**

Test conditions and configurations which are not including in this clause shall comply with the general requirements.

## **8.1 General**

The primary functions of the radio equipment to be assessed during and after EMC exposure:

- the intended functions of the radio equipment which shall be in accordance with the documentation accompanying the equipment;
- 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 exposure;
- the type of modulation, the characteristics of the transmission used for testing (random bit stream, message format, etc.) and the necessary test equipment delivered to enable the assessment of the EUT;
- the ancillary equipment to be combined with the radio equipment for testing (where applicable);
- an exhaustive list of ports, with the maximum cable lengths allowed, classified as either power or telecommunication/signal/control. Power ports shall further be classified as AC or DC power;
- the bandwidth of the IF filter immediately preceding the demodulator;
- the method to be used to verify that a communication link is established and maintained (if appropriate);
- the operating frequency bands over which the equipment is intended to operate;
- any equipment thermal limitation which prevent continuous testing of the EUT;
- the environment(s) in which the equipment is intended to be used.

## **8.2 Equipment which can provide a continuous communication link**

For radio equipment or for radio equipment tested in combination with ancillary equipment, the normal test modulation, test arrangements, etc., shall apply.

## **8.3 Equipment which cannot provide a continuous communication link**

For radio equipment which does not provide a continuous communication link and/or ancillary equipment intended to be tested on a stand-alone basis, the manufacturer shall specify the permissible minimum level of performance or degradation of performance during and/or after EMC exposure.

The manufacturer shall furthermore define the test method(s) for the assessment of the actual level of performance or degradation of performance during and/or after EMC exposure. Under these circumstances the manufacturer shall additionally provide the following information also for inclusion in the test report:

- the functions of the relevant type of the EUT during and after EMC stress;
- the intended functions of the relevant type of the EUT which shall be in accordance with the documentation accompanying the equipment;
- suitable pass/fail criteria for the relevant type of the EUT;
- the method of monitoring the actual level of performance and/or the actual degradation of performance of the EUT;
- the dwell time of the test phenomena at each frequency shall not be less than the time necessary for the EUT to be exercised and able to respond.

The assessment of the actual performance or its degradation which is carried out during and/or after EMC exposure, shall be simple, but at the same time give adequate proof that the primary functions of the equipment are operational.

## **8.4 Ancillary equipment**

At the manufacturer's discretion ancillary equipment may be tested and assessed:

- applying the provisions of this Recommendation:

- separately to the ancillary equipment; or
- to the combination of ancillary and radio equipment;
- applying another appropriate EMC standard.

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

## **8.5 Equipment classification**

For the purpose of the EMC performance assessment in this Recommendation, the radio equipment and/or associated ancillary EUT shall be classified into one of the following three classes:

- 1) equipment for fixed use (e.g., base station equipment); or
- 2) equipment for vehicular use (e.g., mobile equipment); or
- 3) equipment for portable use (e.g., portable equipment).

## **9 Performance criteria**

The following performance criteria for immunity tests apply.

### **9.1 Performance criterion A**

The equipment shall continue to operate as intended. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the equipment is used as intended. In some cases, the performance level may be replaced by a permissible loss of performance. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, then either of these may be derived from the product description and documentation, and what the user may reasonably expect from the equipment, if used as intended.

### **9.2 Performance criterion B**

After the test, the equipment shall continue to operate as intended. No degradation of performance is allowed after the application of the phenomena below a performance level specified by the manufacturer, when the equipment is used as intended. In some cases, the performance level may be replaced by a permissible loss of performance. During the test, degradation of performance or loss of function is allowed. However, no change of actual operating state or stored data is allowed. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, then either of these may be derived from the product description and documentation, and what the user may reasonably expect from the equipment if used as intended.

### **9.3 Performance criterion C**

Loss of function is allowed, provided the function is set recoverable or can be restored by the operation of the controls by the user in accordance with the manufacturer's instructions. Functions and information protected by a battery backup shall not be lost.

### **9.4 Specific performance criteria**

**9.4.1 Analogue ports:** The performance of the equipment shall be verified for analogue voice frequency signal ports:

- by measuring the audio signal break-through (demodulated 1 kHz) on the signal port during continuous exposures, in both signal path directions, covering both analogue to digital conversion, and digital to analogue conversion;
- by testing the functionality of the main signal port and the other signal ports after the transient exposures;

- by verifying that corruption of software and data held in memory has not occurred.

**9.4.1.1 Performance criterion A:** The connection must be maintained throughout testing.

During a sweep over the entire frequency range, the noise level measured at each two-wire analogue port at 600  $\Omega$  (ignoring the normal impedance of the port for practical reason) must be less than  $-40$  dBm.

The measurement shall be done selectively with a bandwidth  $\leq 100$  Hz at 1 kHz.

Dialling tones shall be available.

At these selected frequencies:

- it should be possible to establish a connection between any two ports (e.g., between subscriber lines and between a subscriber line and a transmission port);
- it should be possible to terminate a connection in a controlled manner.

**9.4.1.2 Performance criterion B:** Connections shall be maintained throughout the test.

It should be possible to establish a connection between any two ports (e.g., between subscriber lines and between a subscriber line and a transmission port) after the application of the transients; short delays in making a connection are acceptable.

It should be possible to clear a connection in a controlled manner after the application of the transients.

**9.4.1.3 Performance criterion C:** The general performance criterion C applies.

**9.4.2 Digital ports:** The performance of the equipment shall be verified for digital signal ports:

- by measuring the number of induced bit errors on the main signal port during all exposures;
- by testing the functionality of the main signal port and the other signal ports during selected frequency tests and after the exposures;
- by verifying that corruption of software and data held in memory has not occurred.

**9.4.2.1 Performance criterion A:** During the sweep:

The established connections shall be maintained throughout the testing.

- the number of bit errors at the end of each individual disturbance exposure shall not exceed the maximum number of errors expected for normal operation;
- the number of errors is calculated as: (the maximum bit error ratio specified by the manufacturer)  $\times$  (bit rate)  $\times$  (test time).

The test time is taken to be the dwell time at each frequency of the exposure.

**9.4.2.2 Performance criterion B:** The established connection shall be maintained throughout the testing.

It shall be possible to establish a connection between two ports after the end of transient disturbances.

It shall be possible to clear a connection in a controlled manner after the end of a test signal.

**9.4.2.3 Performance criterion C:** The general performance criterion C applies.

**9.4.3 Ethernet and packet-data interfaces:** To the interfaces specified in [IEEE 802-3], the criteria below apply:

**9.4.3.1 Performance criterion A:** For interfaces which are intended for the transmission of third-party data traffic, a selected port shall be connected to test equipment (e.g., a data communications analyser) as a single point-to-point data link. This will avoid excessive failed transmission attempts caused by data collisions and bus contention problems.

The interface shall be suitably exercised and monitored throughout the test period for erroneous frames.

No more than 5% additional erroneous frames above the quiescent level shall be permitted during the exposure.

The established transmission data rate shall not be degrading for more than 1%.

**9.4.3.2 Performance criterion B:** The data link connection shall be maintained.

**9.4.4 Synchronization interfaces:** The performance of slave clocks specified in [ITU-T G.812] and [ITU-T G.813] shall be checked with the equipment synchronized with an external source.

**9.4.4.1 Performance criterion A:** During the exposure, synchronization shall not be lost.

**9.4.4.2 Performance criterion B:** No alarm indications shall persist after the exposure.

The functional performance according to the manufacturer's specification shall be verified following cessation of the exposure.

**9.4.5 Remote alarm interfaces:** These interfaces are defined by the manufacturer.

**9.4.5.1 Performance criterion A:** No false alarms shall occur during continuous exposures.

**9.4.5.2 Performance criterion B:** No false alarm indications shall persist after the exposure.

## **10 Test report**

General guidance for compiling a test report can be found in [ISO/IEC 17025]. Sufficient details, including, where appropriate, photographs of the test configuration, shall be provided to facilitate reproducibility.

The test report shall describe any special measures that were required to ensure EMC compliant operation of the EUT. One example would be the need to use shielded or special cables.



## Annex A

### Emission requirements

(This annex forms an integral part of this Recommendation.)

**Table A.1 – Equipment intended for telecommunication centres**

	Frequency	Detector	Limits	Basic standard	Remarks
<i>Enclosure port</i>					
Radiated electromagnetic field	30 to 230 MHz	Quasi-peak	40 dB( $\mu$ V/m)	[CISPR 16-1-4]	Note 3
	230 to 1000 MHz	Quasi-peak	47 dB( $\mu$ V/m)		
	1 to 3 GHz	Peak	76 dB( $\mu$ V/m)	[CISPR 16-2-3]	Note 4, Note 6
		Average	56 dB( $\mu$ V/m)		
	3 to 6 GHz	Peak	80 dB( $\mu$ V/m)		
Average		60 dB( $\mu$ V/m)			
6 to 40 GHz	Peak	80 dB( $\mu$ V/m)			
		Average	60 dB( $\mu$ V/m)		
<i>Telecommunication ports (outdoor and indoor)</i>					
Conducted disturbance voltage	0.15 to 0.5 MHz	Quasi-peak	97 to 87 dB( $\mu$ V)	[CISPR 16-1-2]	Note 1, Note 2
		Average	53 to 43 dB( $\mu$ A) 84 to 74 dB( $\mu$ V) or 40 to 30 dB( $\mu$ A)	[CISPR 16-2-2]	
	0.5 to 30 MHz	Quasi-peak	87 dB( $\mu$ V)		Note 1, Note 2
		Average	43 dB( $\mu$ A) 74 dB( $\mu$ V) or 30 dB( $\mu$ A)		
<i>AC mains ports</i>					
Conducted disturbance voltage	0.15 to 0.5 MHz	Quasi-peak	79 dB( $\mu$ V)	[CISPR 16-1-2]	
		Average	66 dB( $\mu$ V)		
	0.5 to 30 MHz	Quasi-peak	73 dB( $\mu$ V)	[CISPR 16-2-1]	
		Average	60 dB( $\mu$ V)		
<i>DC power ports</i>					
Conducted disturbance voltage	0.15 to 0.5 MHz	Quasi-peak	79 dB( $\mu$ V)	[CISPR 16-1-2]	Note 5
		Average	66 dB( $\mu$ V)		
	0.5 to 30 MHz	Quasi-peak	73 dB( $\mu$ V)	[CISPR 16-2-1]	
		Average	60 dB( $\mu$ V)		
<p>NOTE 1 – The limits decrease linearly with the logarithm of the frequency.</p> <p>NOTE 2 – Equivalent current limit can be applied.</p> <p>NOTE 3 – The limits are given for 10 metres measurement distance.</p> <p>NOTE 4 – The limits are given for 3 metres measurement distance.</p> <p>NOTE 5 – DC power port may be a DC power input or output port, connecting to a local DC power network or to a power generating equipment (battery or PV system) with a cable length exceeding 30 m.</p> <p>NOTE 6 – [CISPR 16-1-4] and [CISPR 16-2-3] define the test instrumentation and the test method up to 18 GHz, respectively. For the test instrumentation and test method in the frequency range from 18 GHz to 40 GHz, [b-ANSI C63.4] shall apply.</p>					

**Table A.2 – Equipment intended for customer premises and outside plants**

	Frequency	Detector	Limits	Basic standard	Remarks
<i>Enclosure port</i>					
Radiated electromagnetic field	30 to 230 MHz	Quasi-peak	30 dB(μV/m)	[CISPR 16-1-4] [CISPR 16-2-3]	Physically large systems should be tested according to [ITU-T K.38] Note 3
	230 to 1000 MHz	Quasi-peak	37 dB(μV/m)		
	1 to 3 GHz	Peak Average	70 dB(μV/m) 50 dB(μV/m)		
	3 to 6 GHz	Peak Average	74 dB(μV/m) 54 dB(μV/m)		Note 4, Note 6
	6 to 40 GHz	Peak Average	74 dB(μV/m) 54 dB(μV/m)		
<i>Telecommunication ports (outdoor and indoor)</i>					
Conducted disturbance voltage	0.15 to 0.5 MHz	Quasi-peak  Average	84 to 74 dB(μV) Or 40 to 30 dB(μA) 74 to 64 dB(μV) Or 30 to 20 dB(μA)	[CISPR 16-1-2] [CISPR 16-2-1]	Note 1, Note 2
	0.5 to 30 MHz	Quasi-peak  Average	74 dB(μV) Or 30 dB(μA) 64 dB(μV) Or 20 dB(μA)		Note 1, Note 2
<i>AC mains ports</i>					
Conducted disturbance voltage	0.15 to 0.5 MHz	Quasi-peak Average	66 to 56 dB(μV) 56 to 46 dB(μV)	[CISPR 16-1-2] [CISPR 16-2-1]	
	0.5 to 5 MHz	Quasi-peak Average	56 dB(μV) 46 dB(μV)		
	5 to 30 MHz	Quasi-peak Average	60 dB(μV) 50 dB(μV)		
<i>DC power ports</i>					
Conducted disturbance voltage	0.15 to 0.5 MHz	Quasi-peak Average	79 dB(μV) 66 dB(μV)	[CISPR 16-1-2] [CISPR 16-2-1]	Note 5
	0.5 to 30 MHz	Quasi-peak Average	73 dB(μV) 60 dB(μV)		
<p>NOTE 1 – The limits decrease linearly with the logarithm of the frequency.            NOTE 2 – Equivalent current limit can be applied.            NOTE 3 – The limits are given for 10 metres measurement distance.            NOTE 4 – The limits are given for 3 metres measurement distance.            NOTE 5 – DC power port may be a DC power input or output port, connecting to a local DC power network or to a power generating equipment (battery or PV system) with a cable length exceeding 30m.            NOTE 6 – [CISPR 16-1-4] and [CISPR 16-2-3] define the test instrumentation and the test method up to 18 GHz, respectively. For test instrumentation and test method in the frequency range from 18 GHz to 40 GHz, [b-ANSI C63.4] shall apply.</p>					

## Annex B

### Immunity requirements

(This annex forms an integral part of this Recommendation.)

**Table B.1 – Equipment intended for telecommunication centre**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
<i>Enclosure port</i>						
Electrostatic discharge	kV	4 (Contact) 4 (Air)	6 (Contact) 8 (Air)	[IEC 61000-4-2]	B	
Radio-frequency electro-magnetic field	MHz	80~690	80~690	[IEC 61000-4-3]	A	
	V/m %AM 1 kHz)	3 80	10 80			
		690~6000 10 80	690~6000 20 80			
Power-frequency magnetic field	Hz A/m (r.m.s.)	-	50 3	[IEC 61000-4-8]	A	Note 16, 17
<i>Outdoor telecommunication ports (Note 1)</i>						
Electrical fast transients/bursts	kV (T <sub>r</sub> /T <sub>h</sub> ) ns repetition rate kHz	0.5 5/50 5	1 5/50 5	[IEC 61000-4-4]	B	Note 3
Radio-frequency conducted continuous	MHz V %AM 1 kHz)	0.15 ~ 80 3 80	0.15 ~ 80 10 80	[IEC 61000-4-6]	A	Note 4, 14
Surges	(T <sub>r</sub> /T <sub>h</sub> )μs kV kV	1.2/50 0.5(line to line) 1(line to ground)	1.2/50 0.5(line to line) 1(line to ground)	[IEC 61000-4-5]	B	Note 5, 7
		10/700 0.5(line to line) 1(line to ground)	10/700 0.5(line to line) 1(line to ground)			Note 15
<i>Indoor telecommunication ports</i>						
Electrical fast transients/bursts	kV (T <sub>r</sub> /T <sub>h</sub> ) ns repetition rate kHz	0.5 5/50 5	1 5/50 5	[IEC 61000-4-4]	B	Note 2, 3

**Table B.1 – Equipment intended for telecommunication centre**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks	
		Basic level	Enhanced level				
Radio-frequency conducted continuous	MHz	0.15~80	0.15~80	[IEC 61000-4-6]	A	Note 2, 4, 14	
	V	3	10				
	%AM(1 kHz)	80	80				
Surges	(T <sub>r</sub> /T <sub>h</sub> )µs	1.2/50(8/20)	1.2/50(8/20)	[IEC 61000-4-5]	B	Note 5, 6	
	kV	0.5(line to ground)	0.5(line to ground)				
<i>AC power port</i>							
Electrical fast transients/bursts	kV	1	2	[IEC 61000-4-4]	B		
	(T <sub>r</sub> /T <sub>h</sub> )ns	5/50	5/50				
	kHz	5	5				
Radio-frequency conducted continuous	MHz	0.15~80	0.15~80	[IEC 61000-4-6]	A	Note 4, 14	
	V	3	10				
	%AM(1 kHz)	80	80				
Surges	(T <sub>r</sub> /T <sub>h</sub> )µs	1.2/50(8/20)	1.2/50(8/20)	[IEC 61000-4-5]	B B		
	kV	1(line to line)	1(line to line)				
	kV	2(line to ground)	2(line to ground)				
Voltage dips & interruption	% reduction period	>95		[IEC 61000-4-11]	B	Note 8	
		0.5					
		30					C
		25					C
		>95					
		250					
<i>DC power port</i>							
Fast transients	kV	0.5	1	[IEC 61000-4-4]	B	Note 2, 3	
	(T <sub>r</sub> /T <sub>h</sub> )ns	5/50	5/50				
	repetition rate kHz	5	5				
Radio-frequency conducted continuous	MHz	0.15~80	0.15~80	[IEC 61000-4-6]	A	Note 2, 4, 14	
	V	3	10				
	%AM(1 kHz)	80	80				
Surges	(T <sub>r</sub> /T <sub>h</sub> )µs	1.2/50(8/20)		[IEC 61000-4-5]	B B		
	kV	0.5(line to line)					
	kV	1(line to ground)					

**Table B.1 – Equipment intended for telecommunication centre**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
Voltage dips	% of nominal voltage UT Duration time s	0 0,004		[IEC 61000-4-29]	A (Notes 9, 10, 12 and 13)	high impedance (output impedance of test generator)
Voltage dips	% of nominal voltage UT Duration time s	0 0,01 and 0,1		[IEC 61000-4-29]	C (Note 11)	high impedance (output impedance of test generator)
Voltage dips	% of nominal voltage UT Duration time s	0 0,004		[IEC 61000-4-29]	A (Notes 9, 10, 12 and 13)	low impedance (output impedance of test generator)
Voltage dips	% of nominal voltage UT Duration time s	0 0,01 and 0,1		[IEC 61000-4-29]	C (Note 11)	low impedance (output impedance of test generator)
Abnormal voltage	% of nominal voltage UT Duration time s	0 to 90 1		[IEC 61000-4-29]	C (Note 11)	
Abnormal voltage	% of nominal voltage UT Duration time s	110 to 125 1		[IEC 61000-4-29]	C (Note 11)	
Voltage variation	% of nominal voltage UT Duration time s	100 to 90 2		[IEC 61000-4-29]	A	The test simulates a change in the DC voltage from the nominal value to a lower value

**Table B.1 – Equipment intended for telecommunication centre**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
Voltage variation	% of nominal voltage UT Duration time s	100 to 110  2		[IEC 61000-4-29]	A	The test simulates a change in the DC voltage from the nominal value to a lower value
<p>NOTE 1 – Outdoor lines carrying DC power with superimposed signals shall be treated as outdoor signal lines.</p> <p>NOTE 2 – Only applies when the overall cable length between the EUT and another item of active equipment may be greater than 3 m.</p> <p>NOTE 3 – The repetition rate for xDSL port shall be 100 kHz. Re-testing of equipment tested according to the earlier version of the basic standard with the repetition rate of 5 kHz is not required.</p> <p>NOTE 4 – The test level can be defined as equivalent current into 150 Ω.</p> <p>NOTE 5 – This test may not be applied for unscreened cable when appropriate CDN does not exist.</p> <p>NOTE 6 – Only applies when the overall cable length between the EUT and another item of active equipment may be greater than 30 m.</p> <p>NOTE 7 – This test applies to symmetrical/unsymmetrical screened cables and to coaxial cables.</p> <p>NOTE 8 – This test applies to equipment having a rated input current not exceeding 16 A per phase.</p> <p>NOTE 9 – In some sensitive equipment, momentary and temporary interruption of the service may occur as a result of such transients. Lengthening of the interruption to service (equipment is not functioning as intended) due to the recovery of software shall be taken into account. More detailed information about the service interruption shall be provided by the manufacturer on the request of the operator.</p> <p>NOTE 10 – To prevent system malfunctioning, additional arrangements concerning the power supply system may be necessary.</p> <p>For example:</p> <ul style="list-style-type: none"> <li>– dual feeding system;</li> <li>– high Ohmic distribution system;</li> <li>– Independent power distribution.</li> </ul> <p>NOTE 11 – Following the restoration of the supply to the normal voltage range, the power conversion and management systems shall automatically restore service. The equipment shall then resume operation according to its specifications. The abnormal service voltage shall not lead to the disconnection of the power supply e.g., by causing circuit breakers, fuses or other such devices to operate.</p> <p>NOTE 12 – For equipment with a low priority of service, it is acceptable to use the following performance criteria during the test: "Loss of function is allowed, the function can be restored by a manual operation of the user in accordance with the manufacturer's instructions. Functions and information protected by a battery backup shall not be lost."</p> <p>NOTE 13 – This test is applicable only in equipment in which the battery backup is not permanently connected to the DC distribution system.</p> <p>NOTE 14 – The test for enhanced level is 10 V except for the ITU-T broadcast frequency band: 47 MHz to 68 MHz where the test level shall be 3 V.</p> <p>NOTE 15 – This test applies to symmetrical and unsymmetrical unscreened cables.</p> <p>NOTE 16 – This test applicable only to equipment containing devices susceptible to magnetic fields, such as cathode ray tube (CRT) monitors, Hall elements, electrodynamic microphones, magnetic field sensors, etc.</p>						

**Table B.1 – Equipment intended for telecommunication centre**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
<p>NOTE 17 – For CRTs the acceptable jitter depends upon the character size and is computed for a test level of 1 A/m as follows:                      Jitter (mm) = (3-character height in mm 1)/ 40.                      As jitter is linearly proportional to the magnetic field strength tests can be carried out at other test levels extrapolating the maximum jitter level appropriately.                      NOTE 18 – This test only applies to ports for unscreened pair cables longer than 500 m.</p>						

**Table B.2 – Equipment intended for customer premises**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
<i>Enclosure port</i>						
Electrostatic discharge	kV	6 (Contact)	8(Contact)	[IEC 61000-4-2]	B	
	kV	8(Air)	15(Air)			
Radio-frequency electro-magnetic field	MHz	80~690	80~690	[IEC 61000-4-3]	A	
	V/m	3	10			
	% AM(1 kHz)	80	80			
		690~6000	690~6000			
		10	20			
		80	80			
Power-frequency magnetic field	Hz	50	50	[IEC 61000-4-8]	A	Note 15, 16
	A/m (r.m.s.)	3	3			
<i>Outdoor telecommunication ports (Note 1)</i>						
Fast transients	kV	0.5	1	[IEC 61000-4-4]	B	Note 3
	(T <sub>r</sub> /T <sub>h</sub> )ns	5/50	5/50			
	repetition rate kHz	5	5			
Radio-frequency conducted continuous	MHz	0.15 ~ 80	0.15 ~ 80	[IEC 61000-4-6]	A	Note 4
	V	3	10			
	% AM(1 kHz)	80	80			
Surges	(T <sub>r</sub> /T <sub>h</sub> )µs	1.2/50	1.2/50	[IEC 61000-4-5]	B	Note 5, 7
		0.5(line to line)	0.5(line to line)			
		1(line to ground)	1(line to ground)			
	kV	10/700	10/700			Note 17
	kV	1(line to ground)	0.5(line to line)			
			1(line to ground)			
<i>Indoor telecommunication ports</i>						
Fast transients	kV	0.5	1	[IEC 61000-4-4]	B	Note 3
	(T <sub>r</sub> /T <sub>h</sub> ) ns	5/50	5/50			
	repetition	5	5			

**Table B.2 – Equipment intended for customer premises**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
	rate kHz					
Radio-frequency conducted continuous	MHz V % AM(1 kHz)	0.15~80 3 80	0,15 to 80 10 80	[IEC 61000-4-6]	A	Note 2, 4
Surges	(T <sub>r</sub> /T <sub>h</sub> )µs kV	1.2/50(8/20) 0.5(line to ground)	1,2/50 (8/20) 0,5(line to ground)	[IEC 61000-4-5]	B	Note 5, 6, 14
<i>AC power port</i>						
Fast transients	kV (T <sub>r</sub> /T <sub>h</sub> )ns kHz	1 5/50 5	2 5/50 5	[IEC 61000-4-4]	B	Note 3
Radio-frequency conducted continuous	MHz V % AM(1 kHz)	0.15~80 3 80	0.15~80 10 80	[IEC 61000-4-6]	A	Note 4
Surges	(T <sub>r</sub> /T <sub>h</sub> )µs kV kV	1.2/50(8/20) 1(line to line) 2(line to ground)	1.2/50(8/20) 2(line to line) 4(line to ground)	[IEC 61000-4-5]	B B	
Voltage dips & interruption	% reduction period	>95 1 30 25 >95 250		[IEC 61000-4-11]	B C C	Note 8
<i>DC power port</i>						
Fast transients	kV (T <sub>r</sub> /T <sub>h</sub> )ns repetition rate kHz	1 5/50 5	2 5/50 5	[IEC 61000-4-4]	B	Note 3
Radio-frequency conducted continuous	MHz V % AM(1 kHz)	0.15~80 3 80	0.15~80 10 80	[IEC 61000-4-6]	A	Note 2, 4
Surges	(T <sub>r</sub> /T <sub>h</sub> )µs kV kV	1.2/50(8/20) 0.5(line to line) 1(line to ground)		[IEC 61000-4-5]	B B	
Voltage dips	% of nominal voltage UT Duration	0 0,004		[IEC 61000-4-29]	A (Notes 9, 10, 12 and 13)	high impedance (output impedance of test



**Table B.2 – Equipment intended for customer premises**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
	time s					generator)
Voltage dips	% of nominal voltage UT Duration time s	0  0,01 and 0,1		[IEC 61000-4-29]	C (Note 11)	high impedance (output impedance of test generator)
Voltage dips	% of nominal voltage UT Duration time s	0  0,004		[IEC 61000-4-29]	A (Notes 9, 10, 12 and 13)	low impedance (output impedance of test generator)
Voltage dips	% of nominal voltage UT duration time s	0  0,01 and 0,1		[IEC 61000-4-29]	C (Note 11)	low impedance (output impedance of test generator)
Abnormal voltage	% of nominal voltage UT Duration time s	0 to 90  1		[IEC 61000-4-29]	C (Note 11)	
Abnormal voltage	% of nominal voltage UT Duration time s	110 to 125  1		[IEC 61000-4-29]	C (Note 11)	
Voltage variation	% of nominal voltage UT Duration time s	100 to 90  2		[IEC 61000-4-29]	A	The test simulates a change in the DC voltage from the nominal value to a lower value
Voltage variation	% of nominal voltage UT Duration time s	100 to 110  2		[IEC 61000-4-29]	A	The test simulates a change in the DC voltage from the nominal

**Table B.2 – Equipment intended for customer premises**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
						value to a lower value
<p>NOTE 1 – Outdoor lines carrying DC power with superimposed signals shall be treated as outdoor signal lines.</p> <p>NOTE 2 – Only applies when the overall cable length between the EUT and another item of active equipment may be greater than 3 m.</p> <p>NOTE 3 – The repetition rate shall be 100 kHz. Re-testing of equipment tested according to the earlier version of the basic standard with the repetition rate of 5 kHz is not required.</p> <p>NOTE 4 – The test level can be defined as equivalent current into 150 Ω.</p> <p>NOTE 5 – This test may not be applied for unscreened cable when appropriate CDN does not exist.</p> <p>NOTE 6 – Only applies when the overall cable length between the EUT and another item of active equipment may be greater than 30 m.</p> <p>NOTE 7 – This test applies to symmetrical/unsymmetrical screened cables and to coaxial cables.</p> <p>NOTE 8 – This test applies to equipment having a rated input current not exceeding 16 A per phase.</p> <p>NOTE 9 – In some sensitive equipment, momentary and temporary interruption of the service may occur as a result of such transients. Lengthening of the interruption to service (equipment is not functioning as intended) due to the recovery of software shall be taken into account. More detailed information about the service interruption shall be provided by the manufacturer on the request of the operator.</p> <p>NOTE 10 – To prevent system malfunctioning, additional arrangements concerning the power supply system may be necessary.</p> <p>For example:</p> <ul style="list-style-type: none"> <li>– dual feeding system;</li> <li>– high Ohmic distribution system;</li> <li>– independent power distribution.</li> </ul> <p>NOTE 11 – Following the restoration of the supply to the normal voltage range, the power conversion and management systems shall automatically restore service. The equipment shall then resume operation according to its specifications. The abnormal service voltage shall not lead to the disconnection of the power supply e.g., by causing circuit breakers, fuses or other such devices to operate.</p> <p>NOTE 12 – For equipment with a low priority of service, it is acceptable to use the following performance criteria during the test: "Loss of function is allowed, the function can be restored by a manual operation of the user in accordance with the manufacturer's instructions. Functions and information protected by a battery backup shall not be lost."</p> <p>NOTE 13 – This test is applicable only in equipment in which the battery backup is not permanently connected to the DC distribution system.</p> <p>NOTE 14 – The EUT shall not be reset when the powered surge test be conducted for PoE.</p> <p>NOTE 15 – This test applicable only to equipment containing devices susceptible to magnetic fields, such as CRT monitors, Hall elements, electrodynamic microphones, magnetic field sensors, etc.</p> <p>NOTE 16 – For CRTs the acceptable jitter depends upon the character size and is computed for a test level of 1 A/m as follows:</p> <p>Jitter (mm)= (3 character height in mm 1)/ 40</p> <p>As jitter is linearly proportional to the magnetic field strength tests can be carried out at other test levels extrapolating the maximum jitter level appropriately.</p> <p>NOTE 17 – This test applies to symmetrical and unsymmetrical unscreened cables.</p> <p>NOTE 18 – This test only applies to ports for unscreened pair cables longer than 500 m.</p>						

**Table B.3 – Equipment intended for outside plant**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
<i>Enclosure port</i>						
Electrostatic discharge	kV	6 (Contact) 8 (Air)	8 (Contact) 15 (Air)	[IEC 61000-4-2]	B	
Radio-frequency electro-magnetic field	MHz V/m %AM (1 kHz)	80~690 3 80	80~690 10 80	[IEC 61000-4-3]	A	
		690~6000 10 80	80~690 20 80			
Power-frequency magnetic field	Hz A/m (r.m.s.)	50 3	50 3	[IEC 61000-4-8]	A	
<i>Outdoor telecommunication ports (Note 1)</i>						
Fast transients	kV (T <sub>r</sub> /T <sub>h</sub> )ns repetition rate kHz	0.5 5/50 5	1 5/50 5	[IEC 61000-4-4]	B	Note 3
Radio-frequency conducted continuous	MHz V %AM (1 kHz)	0.15 ~ 80 3 80	0.15 ~ 80 10 80	[IEC 61000-4-6]	A	Note 4
Surges	(T <sub>r</sub> /T <sub>h</sub> )μs kV kV	10/700 us 1 (line to ground)	10/700 us 0.5 (line to line) 1 (line to ground)	[IEC 61000-4-5]	B	Note 5, 7
		1.2/50 us 0.5 (line to line) 1 (line to ground)	1.2/50 us 0.5 (line to line) 1 (line to ground)			Note 5, 17
<i>AC power port</i>						
Fast transients	kV (T <sub>r</sub> /T <sub>h</sub> )ns kHz	1 5/50 5	2 5/50 5	[IEC 61000-4-4]	B	Note 3
Radio-frequency conducted continuous	MHz V %AM 1 kHz)	0.15~80 3 80	0.15~80 10 80	[IEC 61000-4-6]	A	Note 4

**Table B.3 – Equipment intended for outside plant**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
Surges	(T <sub>r</sub> /T <sub>h</sub> )µs kV kV	1.2/50(8/20) 1 (line to line) 2 (line to ground)	1.2/50(8/20) 2 (line to line) 4 (line to ground)	[IEC 61000-4-5]	B B	
Voltage dips & interruption	% reduction period	>95		[IEC 61000-4-11]	B	Note 8
		1			C	
		30				
		25				
		>95			C	
		250				
<i>DC power port</i>						
Fast transients	kV (T <sub>r</sub> /T <sub>h</sub> )ns repetition rate kHz	1 5/50 5	2 5/50 5	[IEC 61000-4-4]	B	Note 2, 3
Radio-frequency conducted continuous	MHz V % AM (1 kHz)	0.15~80 3 80	0.15~80 10 80	[IEC 61000-4-6]	A	Note 2, 4
Surges	(T <sub>r</sub> /T <sub>h</sub> )µs kV kV	1.2/50(8/20) 1 (line to line) 2 (line to ground)		[IEC 61000-4-5]	B B	
Voltage dips	% of nominal voltage UT  Duration time s	0  0,004		[IEC 61000-4-29]	A (Notes 9, 10, 12 and 13)	high impedance (output impedance of test generator)
Voltage dips	% of nominal voltage UT  Duration time s	0  0,01 and 0,1		[IEC 61000-4-29]	C (Note 11)	high impedance (output impedance of test generator)
Voltage dips	% of nominal voltage UT Duration	0		[IEC 61000-4-29]	A (Notes 9, 10, 12 and 13)	low impedance (output impedance of test)

**Table B.3 – Equipment intended for outside plant**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
	time s	0,004				generator)
Voltage dips	% of nominal voltage UT Duration time s	0  0,01 and 0,1		IEC 61000-4-29	C (Note 11)	low impedance (output impedance of test generator)
Abnormal voltage	% of nominal voltage UT Duration time s	0 to 90  1		[IEC 61000-4-29]	C (Notes 11)	
Abnormal voltage	% of nominal voltage UT  Duration time s	110 to 125  1		[IEC 61000-4-29]	C (Notes 11)	
Voltage variation	% of nominal voltage UT  Duration time s	100 to 90  2		[IEC 61000-4-29]	A	The test simulates a change in the DC voltage from the nominal value to a lower value
Voltage variation	% of nominal voltage UT  Duration time s	100 to 110  2		[IEC 61000-4-29]	A	The test simulates a change in the DC voltage from the nominal value to a lower value

NOTE 1 – Outdoor lines carrying DC power with superimposed signals shall be treated as outdoor signal lines.

NOTE 2 – Only applies when the overall cable length between the EUT and another item of active equipment may be greater than 3 m.

NOTE 3 – The repetition rate shall be 100 kHz. Re-testing of equipment tested according to the earlier version of the basic standard with the repetition rate of 5 kHz is not required.

NOTE 4 – The test level can be defined as equivalent current into 150 Ω.

**Table B.3 – Equipment intended for outside plant**

Environmental phenomena	Units	Test levels		Basic standard	Performance criteria	Remarks
		Basic level	Enhanced level			
<p>NOTE 5 – This test may not be applied for unscreened cable when appropriate CDN does not exist.</p> <p>NOTE 6 – Only applies when the overall cable length between the EUT and another item of active equipment may be greater than 10 m.</p> <p>NOTE 7 – This test applies to symmetrical/unsymmetrical screened cables and to coaxial cables.</p> <p>NOTE 8 – This test applies to equipment having a rated input current not exceeding 16 A per phase.</p> <p>NOTE 9 – In some sensitive equipment, momentary and temporary interruption of the service may occur as a result of such transients. Lengthening of the interruption to service (equipment is not functioning as intended) due to the recovery of software shall be taken into account. More detailed information about the service interruption shall be provided by the manufacturer on the request of the operator.</p> <p>NOTE 10 – To prevent system malfunctioning, additional arrangements concerning the power supply system may be necessary.</p> <p>For example:</p> <ul style="list-style-type: none"> <li>– dual feeding system;</li> <li>– high Ohmic distribution system;</li> <li>– independent power distribution.</li> </ul> <p>NOTE 11 – Following the restoration of the supply to the normal voltage range, the power conversion and management systems shall automatically restore service. The equipment shall then resume operation according to its specifications. The abnormal service voltage shall not lead to the disconnection of the power supply e.g., by causing circuit breakers, fuses or other such devices to operate.</p> <p>NOTE 12 – For equipment with a low priority of service, it is acceptable to use the following performance criteria during the test: "Loss of function is allowed, the function can be restored by a manual operation of the user in accordance with the manufacturer's instructions. Functions and information protected by a battery backup shall not be lost."</p> <p>NOTE 13 – This test is applicable only in equipment in which the battery backup is not permanently connected to the DC distribution system.</p> <p>NOTE 15 – This test applicable only to equipment containing devices susceptible to magnetic fields, such as CRT monitors, Hall elements, electrodynamic microphones, magnetic field sensors, etc.</p> <p>NOTE 16 – For CRTs the acceptable jitter depends upon the character size and is computed for a test level of 1 A/m as follows:</p> <p>Jitter (mm) = (3 character height in mm) / 40</p> <p>As jitter is linearly proportional to the magnetic field strength tests can be carried out at other test levels extrapolating the maximum jitter level appropriately.</p> <p>NOTE 17 – This test applies to symmetrical and unsymmetrical unscreened cables.</p> <p>NOTE 18 – This test only applies to ports for unscreened pair cables longer than 500 m.</p>						

## Annex C

### Test on PoE port

(This annex forms an integral part of this Recommendation.)

#### C.1 Introduction

This annex applies to power sourcing equipment (PSE) and powered device (PD) equipment as given in [b-IEEE 802.3af] and [b-IEEE 802.3at] as well as similar equipment providing DC voltage up to 60 Vdc over symmetrical pairs for communication.

PoE equipment can be classified as power sourcing equipment or powered equipment.

This annex also focuses on providing additional guidance for emission and immunity measurements on PoE ports of equipment, especially for the PSE equipment supporting multiple PoE ports.

The guidance includes:

- how to exercise ports to maximize the radiation;
- how to reduce the influence from auxiliary equipment;
- monitoring of DC power supply and Ethernet communication performance during immunity tests;
- special coupling and decoupling networks used to facilitate the surge test, considering DC power supply overlapping with the Ethernet signal;
- loading conditions when performing AC voltage dip tests.

#### C.2 Operational condition

The general operational condition in this Recommendation should apply.

For a PSE, as many of the PoE ports as possible should be driven or loaded during measurement. The rated output power of the PoE port or a typical load should be configured.

The PoE port of PSE equipment should be assessed in both powering and un-powering states for surge immunity tests, and should be assessed only in powering state for conducted immunity test items other than surge test.

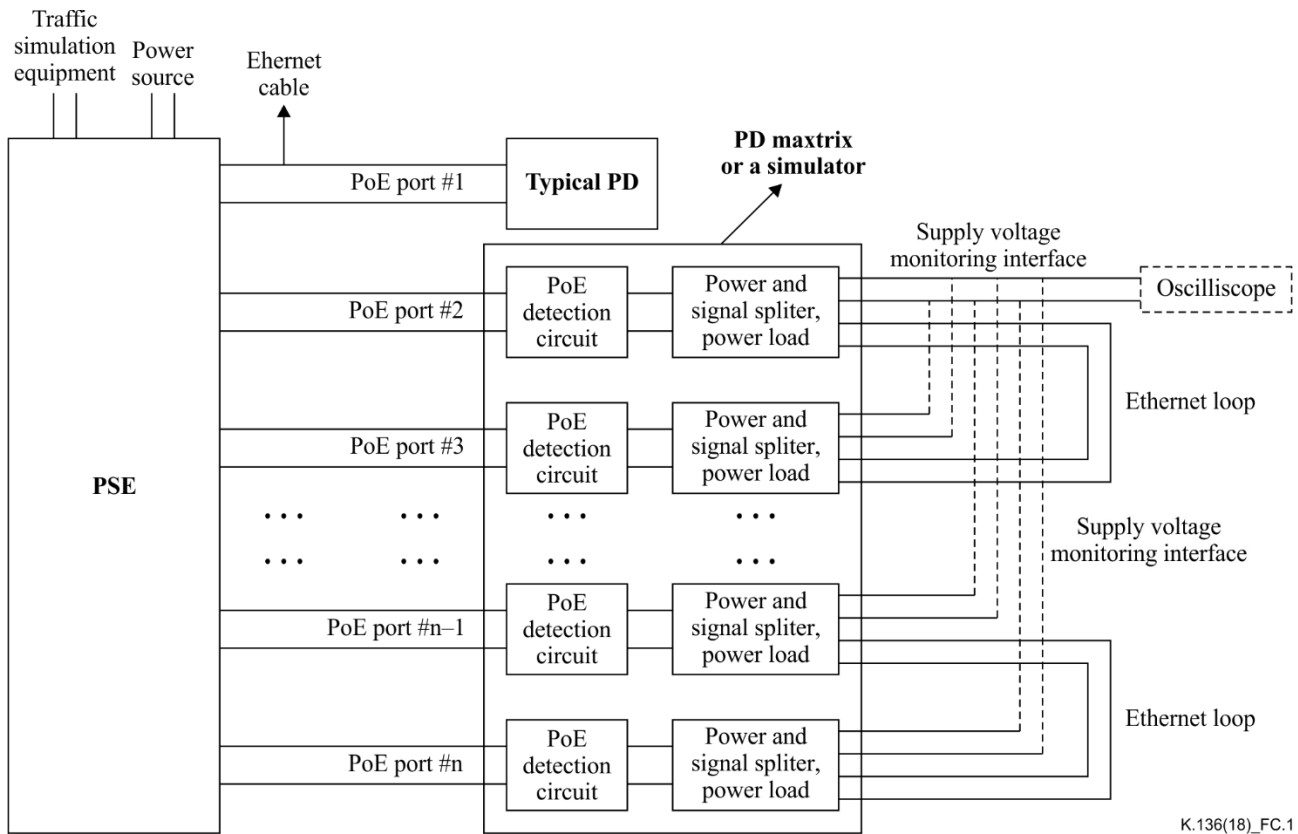
PD should be evaluated in a powered state.

#### C.3 Test configuration

The general test configurations defined in Recommendation should apply.

The test configuration is recommended as shown in Figure C.1. An oscilloscope is not necessary for the EMI test. The PSE termination equipment may be a PD matrix or a simulator, which provides functions including:

- a splitter of DC power and Ethernet;
- power dissipation of DC supply through on-board resistive loads;
- interface for monitoring the supply voltage by using an external oscilloscope or similar instrument;
- RJ45 interface for monitoring the performance of Ethernet by external loopback.



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**Figure C.1 – Test configuration example for PoE EMC testing**

## C.4 Test methods

### C.4.1 Emission test method

The measurement instruments, test site and test method should follow the requirements of [IEC CISPR 32].

The PoE port should be taken as a wired-network port to perform conducted emission measurements, An ISN is recommended to be inserted between the PSE and PD provided that it can withstand the operating voltage and current of PoE.

Using a PD matrix to drive the PSE supporting multi-PoE ports is recommended for radiated emission measurement. However, in some extreme cases, the cable bundle may be so large that it is not easy exiting the chamber, a dummy load which integrates the functions of a PD matrix and has a compact volume as illustrated in Figure C.1 may be a good substitution.

### C.4.2 Immunity test method

The PoE port should be considered as a signal line port to conduct the immunity test. However, since the differential mode surge between DC supply pair may be present due to un-simultaneous operation of the common mode protection components at the PoE port, it is necessary to perform the differential mode surge test.

The equipment grounding and test configuration should be consistent with the actual application. For PSE equipment with multi-PoE ports, a sufficient number of ports should be selected for testing.

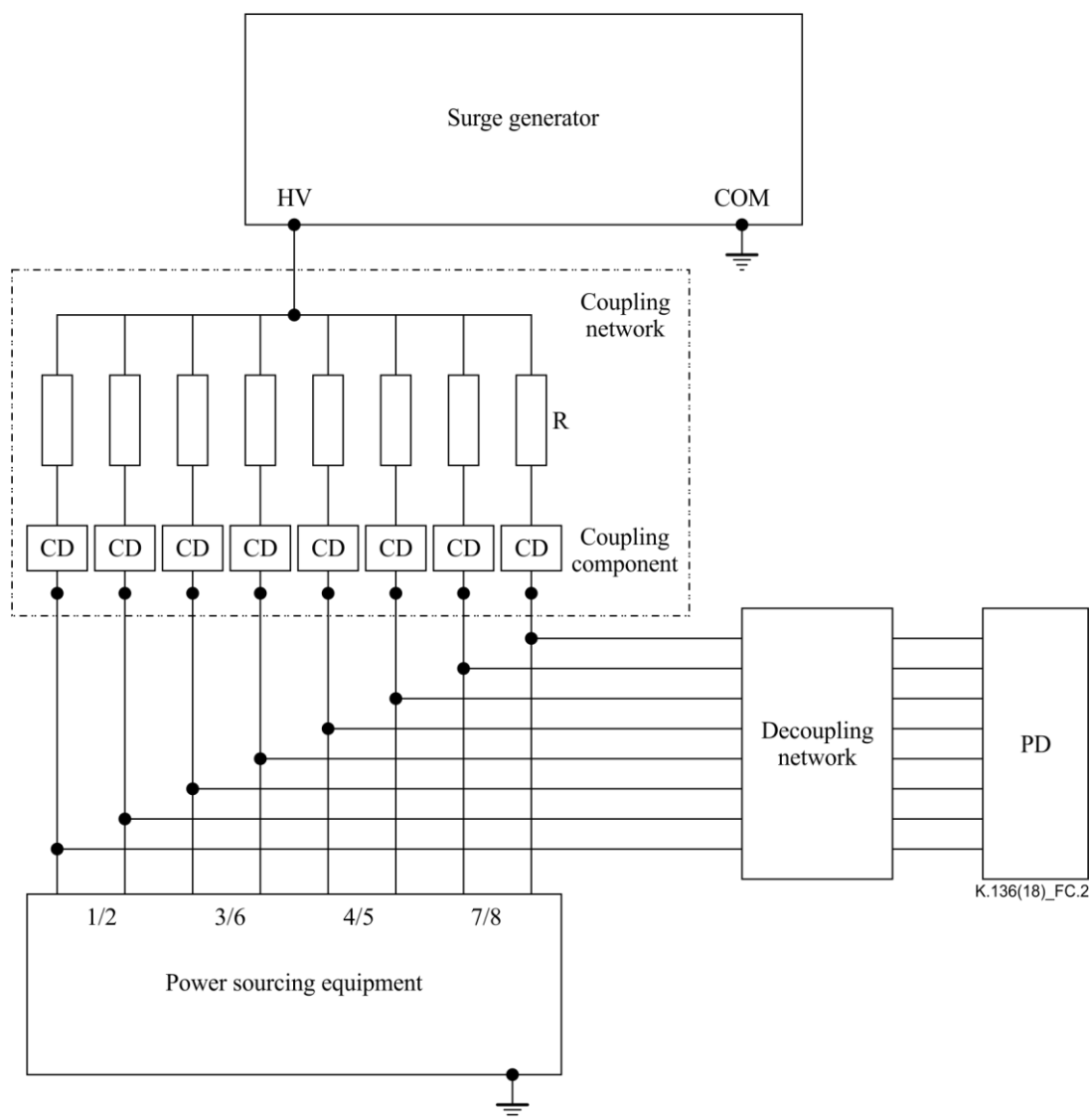
For the surge test of a PoE port in an un-powering state, the PoE port can be directly connected to the surge generator without using a coupling and decoupling network. For surge testing of a PoE port in the powering state, the PoE port should be connected to the surge generator by using a suitable coupling and decoupling network. Decoupling network performance should be good enough not to



affect the test results. Test methods for shielded PoE cables should be performed in accordance with [IEC 61000-4-5] test methods for shielded lines.

Unshielded PoE ports should be tested for both line-to-line and line-to-ground coupling mode, which is defined as follows:

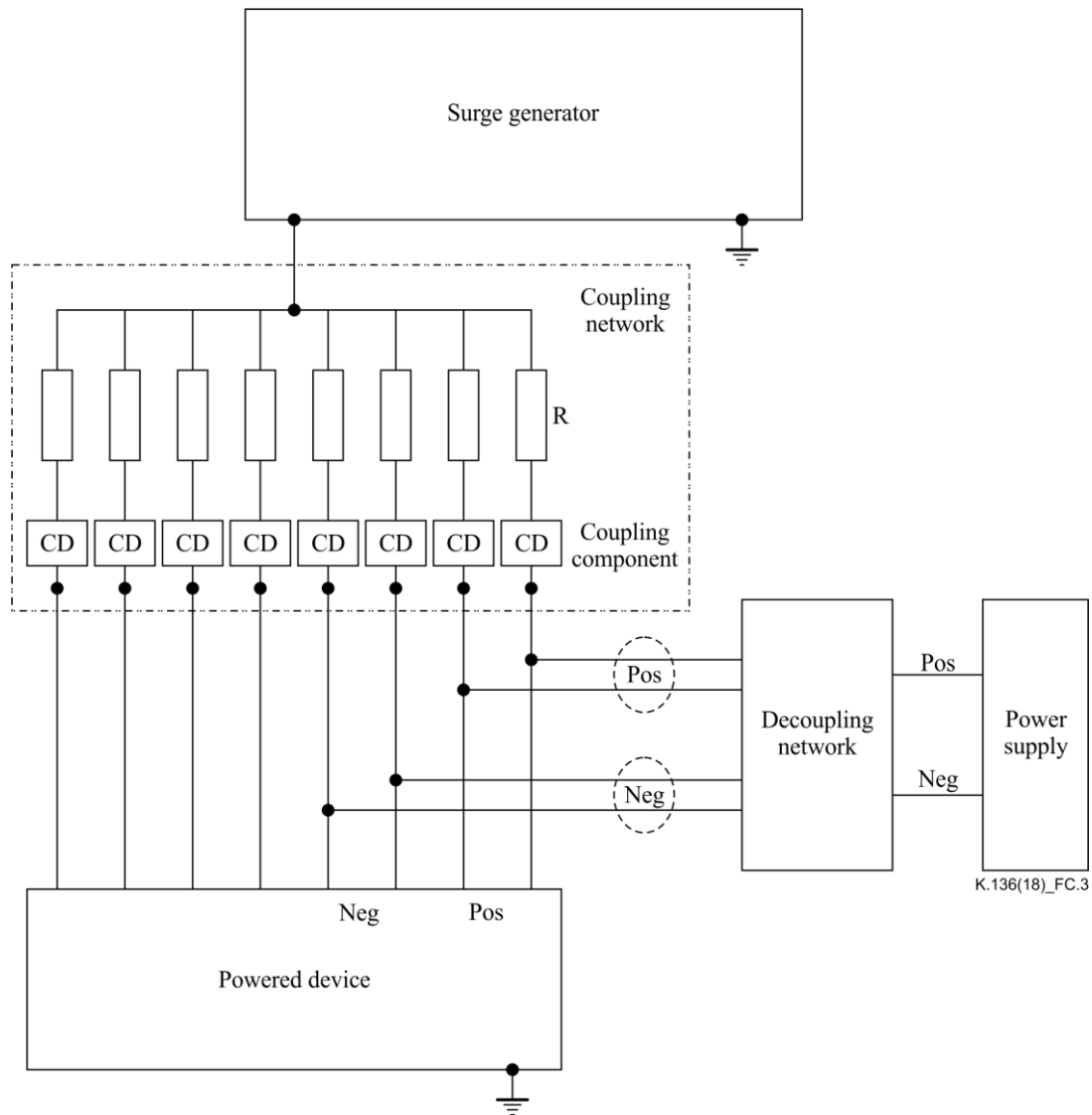
- line-to-ground coupling: All eight lines to ground simultaneously, the test setup for PSE and PD are given in Figures C.2 and C.3, respectively.
- line-to-line coupling: The tests should be performed between the powering pairs, for example 1/2 to 3/6, or 4/5 to 7/8, and the test setup for PSE and PD are given in Figures C.4 and C.5, respectively.



NOTE 1 – For each coupling network, R should not exceed 320  $\Omega$  with indoor cable and should be 25  $\Omega$  with outdoor cables.

NOTE 2 – Coupling and decoupling network for power lines in [IEC 61000-4-5] should be used.

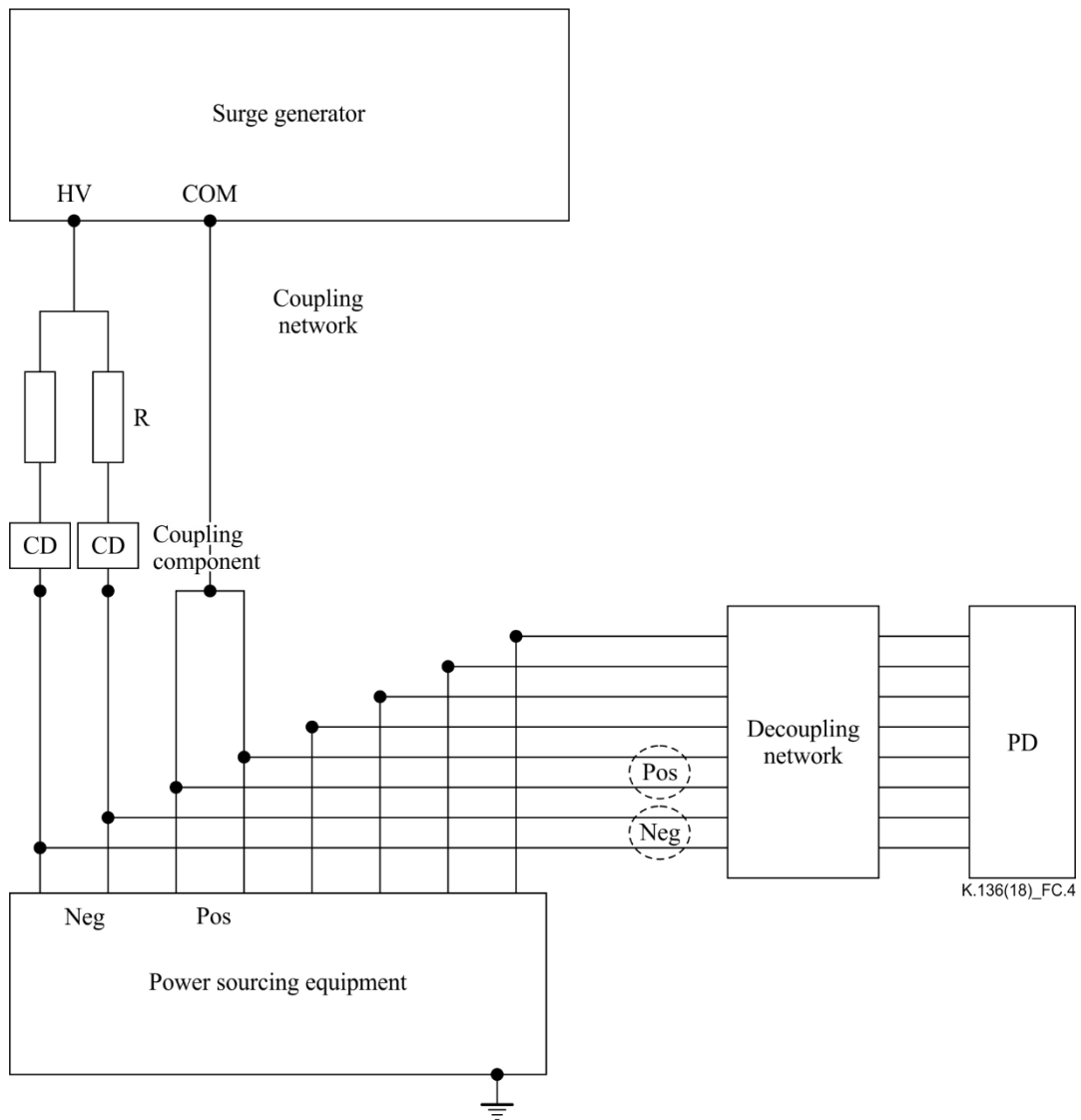
**Figure C.2 – Line-to-ground coupling test configuration for PoE of power sourcing equipment**



NOTE 1 – For each coupling network, R should not exceed 320  $\Omega$  with indoor cable and should be 25 $\Omega$  with outdoor cables.

NOTE 2 – Coupling and decoupling network for power lines in [IEC 61000-4-5] should be used.

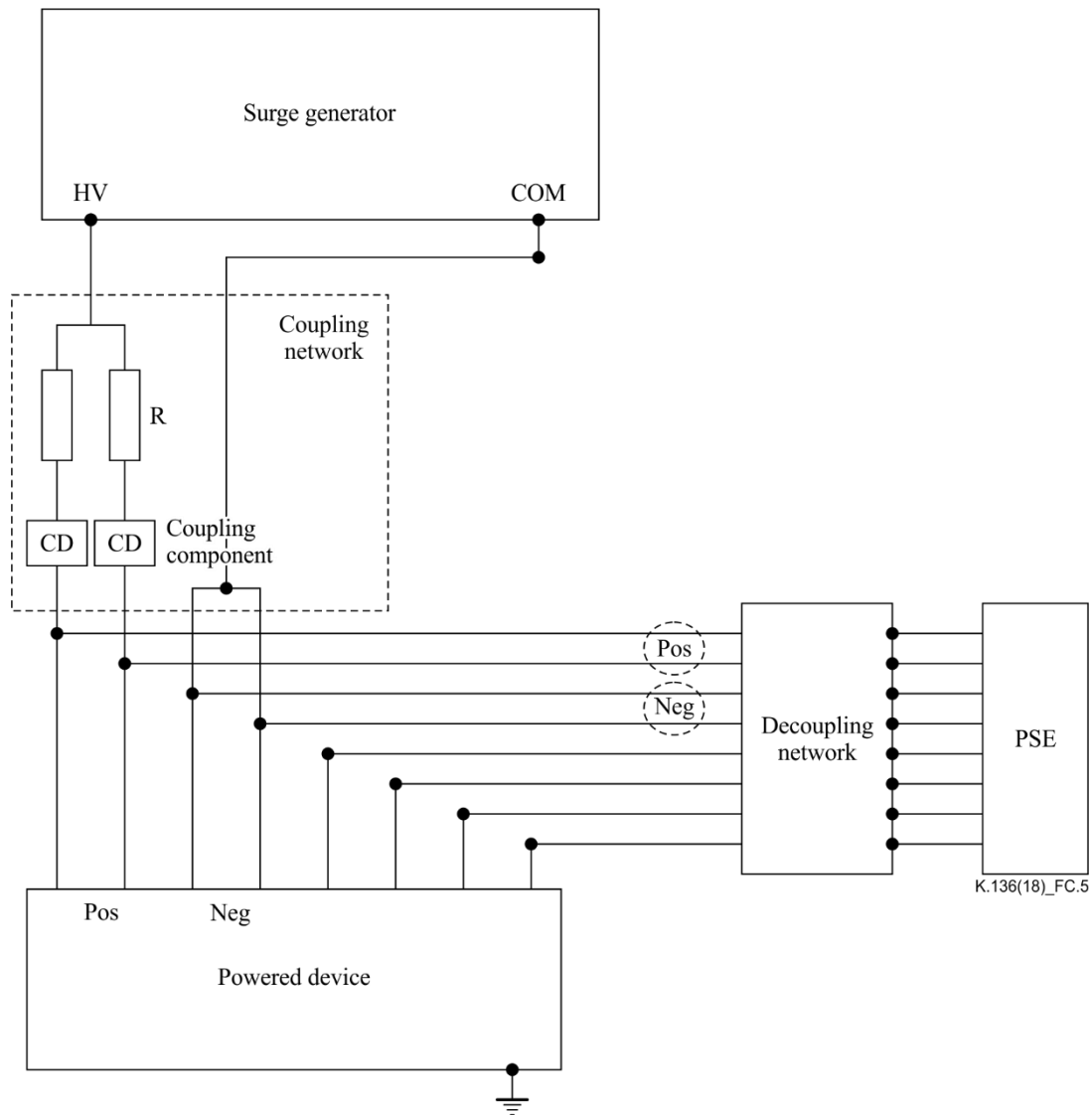
**Figure C.3 – Line-to-ground coupling test configuration for PoE of powered device**



NOTE 1 – For each coupling network, R should be 80  $\Omega$  with indoor cable and 25  $\Omega$  with outdoor cables.

NOTE 2 – Coupling and decoupling network for power lines in [IEC 61000-4-5] should be used.

**Figure C.4 – Line-to-line coupling test configuration for PoE of power sourcing equipment**



NOTE 1 – For each coupling network, R should be 80  $\Omega$  with indoor cable and 25  $\Omega$  with outdoor cables.

NOTE 2 – Coupling and decoupling network for power lines in [IEC 61000-4-5] should be used.

**Figure C.5 – Line-to-line coupling test configuration for PoE of powered device**

## C.5 Performance criteria

When performing a surge test to a PoE port with PoE not supplying the power, the performance should be checked after the test. While performing a surge test to a PoE port with PoE supplying the power, the performance should be checked both during and after the test.

The following specifies the criterion A and criterion B requirements for PoE, and for criterion C the general criterion applies.

### C.5.1 Performance criterion A (continuous phenomena)

The supply voltage of PSE equipment should be monitored at the input interface of a PD and should be in the range 37-57 Vdc as specified by [b-IEEE 802.3] in case of using a 100-m cable or the line simulator. If another line simulator is used, the voltage requirement should be adjusted linearly according to the line resistance and DC current.

No bit error or package loss should occur for PD Ethernet port.

### **C.5.2 Performance criterion B (transient phenomena)**

The application of the test should not cause the system to lose an established connection or to reset. At the cessation of the test, the port should continue to function in the state established prior to the application of the test, without user intervention.

The above performance criteria do not apply to surge testing. During the surge test, the voltage of the PoE port should not be interrupted. At the cessation of the test, the port should continue to function in the state established prior to the application of the test, without user intervention.

### **C.5.3 Performance criterion C (interruptions)**

The general performance criterion C applies.

## Bibliography

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