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## Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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## Template for comments and secretariat observations

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| 1  | 2                                          | (3)                          | 4               | 5                                                                                                                                  | (6)                                                                      | 7                                                  |
|----|--------------------------------------------|------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------|
| MB | Clause No./ Subclause No./Annex (e.g. 3.1) | Paragraph/ Figure/Table/Note | Type of comment | Comment (justification for change) by the MB                                                                                       | Proposed change by the MB                                                | Secretariat observations on each comment submitted |
|    | 3.1                                        | Definition 1                 | ed              | Definition is ambiguous and needs clarifying.                                                                                      | Amend to read '...so that the mains connector to which no connection...' |                                                    |
|    | 6.4                                        | Paragraph 2                  | te              | The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK. | Delete reference to UV photometer.                                       |                                                    |



# 47A/1186/CD

COMMITTEE DRAFT (CD)

|                                             |                                                 |
|---------------------------------------------|-------------------------------------------------|
| PROJECT NUMBER:<br><b>IEC 62228-5 ED2</b>   |                                                 |
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|                                                     |                                   |
|-----------------------------------------------------|-----------------------------------|
| IEC SC 47A : INTEGRATED CIRCUITS                    |                                   |
| SECRETARIAT:<br>Japan                               | SECRETARY:<br>Mr Yoshinori FUKUBA |
| OF INTEREST TO THE FOLLOWING COMMITTEES:            | HORIZONTAL FUNCTION(S):           |
| ASPECTS CONCERNED:<br>Electromagnetic Compatibility |                                   |

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TITLE:

**Integrated circuits - EMC evaluation of transceivers - Part 5: Ethernet transceivers**

NOTE FROM TC/SC OFFICERS:

The draft document was reviewed at SC 47A / WG 9 in London on 2024-11-26, and SC47A decided to circulate CD (47A/1177A/RM : Decision 47A-2024-06) . Edition 2 is developed using Online Standards Development (OSD).

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**Integrated circuits - EMC evaluation of transceivers - Part 5: Ethernet transceivers –**

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The text of this International Standard is based on the following documents:

| Draft      | Report on voting |
|------------|------------------|
| XX/XX/FDIS | XX/XX/RVD        |

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications](http://www.iec.ch/publications).

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- reconfirmed,
- withdrawn, or
- revised.

## Integrated circuits - EMC evaluation of transceivers - Part 5: Ethernet transceivers –

### 1 Scope

This part of IEC 62228 specifies test and measurement methods for EMC evaluation of Ethernet transceiver ICs under network condition. It defines test configurations, test conditions, test signals, failure criteria, test procedures, test setups and test boards. It is applicable for transceiver of the following Ethernet systems

- 10BASE-T1S according to ISO/IEC/IEEE 8802-3/AMD5;
- 100BASE-T1 according to ISO/IEC/IEEE 8802-3:2017/AMD1:2017;
- 100BASE-TX according to ISO/IEC/IEEE 8802-3:2017;
- 1000BASE-T1 according to ISO/IEC/IEEE 8802-3:2017/AMD4:2017
- 2.5/5/10GBASE-T1 according to ISO/IEC/IEEE 8802-3:2017/AMD8:2018;
- 1000BASE-RH according to ISO/IEC/IEEE 8802-3:2017/AMD1:2017;

and covers

- the emission of RF disturbances;
- the immunity against RF disturbances;
- the immunity against impulses;
- the immunity against electrostatic discharges (ESD).

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61000-4-4, *Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test*

IEC 61967-1, *Integrated circuits - Measurement of electromagnetic emissions - Part 1: General conditions and definitions*

IEC 61967-2, *Integrated circuits - Measurement of electromagnetic emissions, 150 kHz to 1 GHz - Part 2: Measurement of radiated emissions - TEM cell and wideband TEM cell method*

IEC 61967-4, *Integrated circuits - Measurement of electromagnetic emissions - Part 4: Measurement of conducted emissions - 1 ohm/150 ohm direct coupling method*

IEC 61967-8, *Integrated circuits - Measurement of electromagnetic emissions - Part 8: Measurement of radiated emissions - IC stripline method*

IEC 62132-1, *Integrated circuits - Measurement of electromagnetic immunity - Part 1: General conditions and definitions*

IEC 62132-2, *Integrated circuits - Measurement of electromagnetic immunity - Part 2: Measurement of radiated immunity - TEM cell and wideband TEM cell method*

IEC 62132-4, *Integrated circuits - Measurement of electromagnetic immunity 150 kHz to 1 GHz - Part 4: Direct RF power injection method*

IEC 62132-8, *Integrated circuits - Measurement of electromagnetic immunity - Part 8: Measurement of radiated immunity - IC stripline method*

IEC 62215-3, *Integrated circuits - Measurement of impulse immunity - Part 3: Non-synchronous transient injection method*

IEC 62228-1, *Integrated circuits - EMC evaluation of transceivers - Part 1: General conditions and definitions*

ISO 7637-2:2011, *Road vehicles — Electrical disturbances from conduction and coupling — Part 2: Electrical transient conduction along supply lines only*

ISO/IEC/IEEE 8802-3:2017, *Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Standard for Ethernet*

ISO/IEC/IEEE 8802-3:2017/AMD1:2017, *Amendment 1 - Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Standard for Ethernet - Physical layer specifications and management parameters for 100 Mb/s operation over a single balanced twisted pair cable (100BASE-T1)*

ISO/IEC/IEEE 8802-3:2017/AMD4:2017, *Amendment 4 - Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Standard for Ethernet - Physical layer specifications and management parameters for 1 Gb/s operation over a single twisted-pair copper cable*

ISO/IEC/IEEE 8802-3:2017/AMD8:2018, *Amendment 8 - Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Standard for Ethernet - Physical layer and management parameters for power over data lines (PoDL) of single balanced twisted-pair ethernet*

ISO 10605:2023, *Road vehicles — Test methods for electrical disturbances from electrostatic discharge*

ISO 21111-2:2020, *Road vehicles — In-vehicle Ethernet — Part 2: Common physical entity requirements*

CISPR 16-1-1, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus*

IEEE 802.3bv:2017, *IEEE Standard for Ethernet - Amendment 9: Physical Layer Specifications and Management Parameters for 1000 Mb/s Operation Over Plastic Optical Fiber*

Electronic Components Industry Association, EIA-198-1, *Ceramic Dielectric Capacitors Classes I, II, III and IV*

### **3 Terms, definitions and abbreviated terms**

#### **3.1 Terms and definitions**

For the purposes of this document, the terms and definitions given in IEC 61967-1, IEC 62132-1, IEC 62228-1, as well as the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <http://www.iso.org/obp>

– IEC Electropedia: available at <http://www.electropedia.org/>

### 3.1.1

#### **10BASE-T1S transceiver**

transceiver 10 Mbit/s via single balanced twisted pair, with a functionality according to ISO/IEC/IEEE 8802-3/AMD5 (10BASE-T1S)

### 3.1.2

#### **100BASE-T1 transceiver**

transceiver 100 Mbit/s via single balanced twisted pair, with a functionality according to ISO/IEC/IEEE 8802-3:2017/AMD1:2017 (100BASE-T1)

### 3.1.3

#### **100BASE-TX transceiver**

transceiver 100 Mbit/s via two balanced twisted pairs, with a functionality according to ISO/IEC/IEEE 8802-3:2017 (100BASE-TX)

### 3.1.4

#### **1000BASE-T1 transceiver**

transceiver 1000 Mbit/s via single balanced twisted pair, with a functionality according to ISO/IEC/IEEE 8802-3:2017/AMD4:2017 (1000BASE-T1)

### 3.1.5

#### **1000BASE-RH transceiver**

transceiver 1000 Mbit/s via **FOT** (fiber optic transceiver) and multi-mode plastic optical fiber, with a functionality according to ISO/IEC/IEEE 8802-3:2017(1000BASE-RH)

### 3.1.6

#### **2.5GBASE-T1 transceiver**

transceiver 2.5 Gbit/s via single balanced twisted pair, with a functionality according to ISO/IEC/IEEE 8802-3:2017/AMD8:2018 (2.5GBASE-T1)

### 3.1.7

#### **5GBASE-T1 transceiver**

transceiver 5 Gbit/s via single balanced twisted pair, with a functionality according to ISO/IEC/IEEE 8802-3:2017/AMD8:2018 (5GBASE-T1)

### 3.1.8

#### **10GBASE-T1 transceiver**

transceiver 10 Gbit/s via single balanced twisted pair, with a functionality according to ISO/IEC/IEEE 8802-3:2017/AMD8:2018 (2.5GBASE-T1)

### 3.1.9

#### **global pin**

pin that carries a signal or power, which enters or leaves the application board without any active component in between

### 3.1.10

#### **local pin**

pin that carries a signal or power, which does not leave the application board

### 3.1.11

#### **mandatory components**

#### **pl**

components needed for proper function and/or technical requirement of IC as specified by the IC manufacturer

### 3.1.12

#### **EAS**

ethernet access switch. IC with integrated Ethernet transceivers and switch functionality as defined in ISO/IEC/IEEE 8802-3:2017

### 3.2 Abbreviated terms

ASIC Application specific integrated circuit

BIN Bus interface network

BIST Built in self-test

CMC Common mode choke

CDMR Common to differential mode conversion ratio

CMR Common mode rejection

CRC Cyclic redundancy check

DCMR Differential to common mode conversion ratio

DPI Direct RF power injection

DTT Data transfer test

DUT Device under test

EEE Energy efficient Ethernet

ETEnd termination

FOT Fiber optic transceiver

FPGA Field programmable gate array

GMII Gigabit media independent interface

GPIO General purpose input or output

IL Insertion loss

INH Inhibit

LCL Longitudinal conversion loss

LPF Low pass filter

MAC Medium access control

MAC-PHY Integration of IEEE Clause 4 [MAC](#) and 10BASE-T1 [PHY](#) in an IC

MDI Medium dependent interface

MII Media independent interface

MSE Mean squared error

OFE Optical frontend

P2P Point-to-point

PCB Printed circuit board

PLCA Physical layer collision avoidance

PMD Physical medium dependent

POF Plastic optical fiber

PRBS Pseudo random bit stream

PHY Interface semiconductor circuit for implementation of the functions of the Ethernet physical layer

RGMII Reduced gigabit media independent interface

RLReturn loss

RS-FEC Reed Solomon forward error correction

SBC System base chip

SFP Small form-factor pluggable

SGMII Serial gigabit media independent interface

SNR Signal-to-noise ratio

S-parameter Scattering parameter

SQI Signal quality indicator

TDR Time domain reflectometry

TI Time interval error

TLP Transmission line pulse

VNA Vector network analyser

WUP Wake-up pulse

## 4 General

The intention of this document is to evaluate the EMC performance of Ethernet transceivers under application conditions in a minimal network.

The definitions, which are common for all included Ethernet transceiver, for test configurations, conditions, test signals, failure criteria, test procedures and test setups are given in the main body of this document. Specific definitions or extensions for those parameters, test requirements and proposed test limit are described in a related annex for each Ethernet transceiver type separately.

The evaluation of the EMC characteristics of Ethernet transceivers shall be performed for the implemented functional operation modes as defined in [Table 1](#) under network condition for conducted RF emission and RF immunity tests, impulse immunity tests and powered ESD tests and on a single transceiver IC for unpowered ESD tests. The specific functional operation modes may differ between the Ethernet systems that are included in this document and are described in detail in the related annexes.

The aim of these tests is to determine the EMC performance on dedicated pins of the Ethernet transceiver which are considered as EMC relevant in the application. For an Ethernet transceiver, these pins are global pins like MDIP, MDIN (only relevant for electrical Ethernet transceiver),  $V_{BAT}$  and WAKE as well as local pins like power supply inputs ( $V_{DDX}$ ). The global pin WAKE is given as an example and represents any global pin other than [MDI](#) and voltage supply  $V_{BAT}$ .

If the [DUT](#) includes additional product specific EMC relevant pins (functions), it shall be tested as well. The test conditions and failure validation criteria shall be adapted to the definitions for the standard functionality of Ethernet transceivers.

The test methods used for the EMC characterization are based on the international standards for IC EMC tests and are described in [Table 1](#).

**Table 1 – Overview of measurements and tests**

| Configuration       | Test                        | Test method                                           | Evaluation | Functional operation mode |
|---------------------|-----------------------------|-------------------------------------------------------|------------|---------------------------|
| Transceiver network | RF conducted emission (EMI) | 150 $\Omega$ direct coupling (IEC 61967-4)            | Spectrum   | Normal                    |
|                     | RF radiated emission        | IC Stripline (IEC 61967-8) or GTEM-Cell (IEC 61967-2) | Spectrum   | Normal                    |
|                     | RF conducted immunity (RF)  | <a href="#">DPI</a> (IEC 62132-4)                     | Function   | Normal                    |
|                     |                             |                                                       |            | Low power                 |
|                     | Impulse immunity (IMP)      | Non-synchronous transient injection (IEC 62215-3)     | Function   | Normal                    |
|                     |                             |                                                       |            | Low power                 |
|                     | RF radiated immunity        | IC Stripline (IEC 62132-8) or GTEM-Cell (IEC 62132-2) | Function   | Normal                    |

|                    |               |                                    |          |           |
|--------------------|---------------|------------------------------------|----------|-----------|
|                    | ESD powered   | Contact discharge (ISO 10605:2023) | Function | Normal    |
|                    |               |                                    |          | Low power |
| Single transceiver | ESD unpowered | Contact discharge (ISO 10605:2023) | Damage   | Unpowered |

The 150  $\Omega$  direct coupling, [DPI](#) and impulse immunity test methods are chosen for the evaluation of the conducted EMC characteristic of transceivers in network condition. These three test methods are based on the same approach using conductive coupling. Therefore, it is possible to use the same test board for all tests in functional operation mode, which reduces the effort and increases the reproducibility and comparability of test results.

For evaluation of radiated RF emission and RF immunity characteristic of an Ethernet transceiver in functional operation mode a minimal Ethernet test network consisting of one Ethernet transceiver ([DUT](#)) and an Ethernet link partner of the same type (including [MDI](#) line termination) is used.

Powered ESD test will be performed using the same approach of testing the Ethernet transceiver under network conditions but a modified test board is used because of RF and ESD tests cannot be combined on one test board if all specific test conditions of each test method should be covered.

The unpowered ESD test is performed on a separate test board with a single transceiver.

All measurements and tests should be done according to the general drawings of schematics given in [Annex G](#) with soldered transceivers on special test boards as described in [Annex H](#) to ensure application like conditions and avoid setup effects by sockets. Recommended limits for Ethernet transceivers in automotive application are given in [Annex I](#).

In general, the test definition is done for Ethernet single transceiver ([PHY](#)). Ethernet transceiver cells embedded in EAS, SBCs or ASICs shall follow the test methods for PHYs, adapting test conditions and targets as necessary. Such adaptations shall be done individually for the dedicated IC but shall follow the general definitions.

If an Ethernet transceiver supports more than one Ethernet system (e.g. 100BASE-T1 and 1000BASE-T1), all tests for the implemented Ethernet systems shall be performed separately and the related annexes shall apply.

In order to verify filter effects on the EMC performance of Ethernet transceivers, configurations with different bus interface networks for [MDI](#) are defined in this document. In consequence the frequency characteristic of these filter elements shall be taken into account for the interpretation of the test results.

## 5 Test and operating conditions

### 5.1 Supply and ambient conditions

For all tests and measurements under operating conditions, the settings are based on systems with 12 V power supply, which is the main application of Ethernet transceivers. If a transceiver is designed or targeted for other power supply voltages, the test conditions and test targets shall be adapted and documented accordingly. The defined supply and ambient conditions for functional operation are given in [Table 2](#).

**Table 2 – Supply and ambient conditions for functional operation**

| Parameter                   | Value                      |
|-----------------------------|----------------------------|
| Voltage supply $V_{BAText}$ | $(14 \pm 0,2)$ V (default) |
| Voltage supply $V_{DDx}$    | $V_{nominal} \pm 2 \%$     |
| Test temperature            | $(23 \pm 5)$ °C            |

For RF emission measurements, the ambient noise floor shall be at least 6 dB below the applied target limit and documented in the test report.

For ESD tests, the requirements of ISO 10605:2023 climatic environmental conditions shall be applied.

## 5.2 Test operation modes

### 5.2.1 General

The Ethernet transceiver shall be tested in functional operation modes and unpowered mode according to [Table 1](#).

Depending on the transceiver the configuration for functional operation modes is controlled by hardware and/or software settings.

### 5.2.2 Transceiver configuration for normal operation mode

For tests in normal functional operation mode, a transceiver configuration according to [Table 3](#) shall be used except for 10Base-T1S transceiver, where the configuration is given in [Annex A](#).

**Table 3 – Definition for transceiver configuration for normal operation mode**

| Topic                     | Content                                                                                                                                                                                                                                                                                                                                                                                     |
|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Transceiver configuration | <ul style="list-style-type: none"><li>– full duplex mode with maximum data rate for <a href="#">DUT</a></li><li>– automatic polarity detection enabled (if implemented)</li><li>– transceiver configuration as specified by semiconductor manufacturer for reference application in datasheet, application note or comparable documentation (to be documented in the test report)</li></ul> |

### 5.2.3 Transceiver configuration for low power mode

For tests in low power mode, a transceiver configuration according to [Table 4](#) shall be used except for 10Base-T1S transceiver, where the configuration is given in [Annex A](#).

**Table 4 – Definition for transceiver mode configuration for low power mode**

| Topic                     | Content                                                                                                                                                                                                                                           |
|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Transceiver configuration | <ul style="list-style-type: none"><li>– transceiver configuration as specified by semiconductor manufacturer for reference application in datasheet, application note or comparable documentation (to be documented in the test report)</li></ul> |

## 5.3 Definition of [BIN](#)

For tests of copper-based transceivers, the following [MDI](#) test networks ([BIN](#)) are defined in general:

- Minimum [MDI](#) interface network (Min-[BIN](#)):
- DC blocking capacitor  $C_{ac1}$ ,  $C_{ac2}$  as illustrated in [Figure 1](#).
- Standard [MDI](#) interface (Std-[BIN](#)):
- DC blocking capacitor  $C_{ac1}$ ,  $C_{ac2}$  and a [CMC](#) as illustrated in [Figure 2](#).
- Optimized [MDI](#) interface (Opt-[BIN](#)):
- DC blocking capacitor  $C_{ac1}$ ,  $C_{ac2}$  and a [CMC](#) a Low pass filter ([LPF](#)) and a ESD suppression devices or terminations defined by semiconductor manufacturer as illustrated in [Figure 3](#). The position of ESD suppression devices within the interface network can either be between transceiver and [CMC](#) and / or between  $C_{ac1}$  and  $C_{ac2}$  and [MDI](#) node.

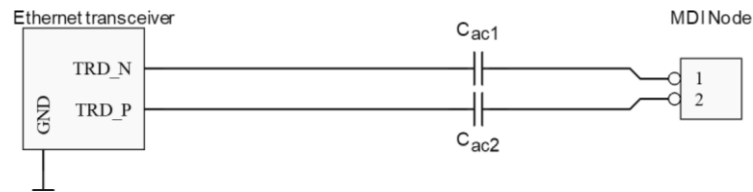


Figure 1 – Minimum MDI interface test network (Min-BIN)

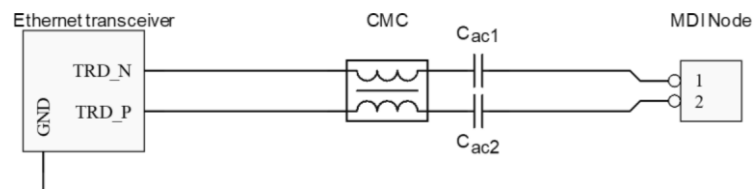


Figure 2 – Standard MDI interface test network (Std-BIN)

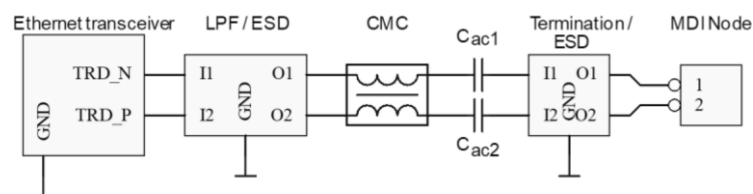


Figure 3 – Optimized MDI interface test network (Opt-BIN)

The application of the different BINs and more detailed definitions are described in the corresponding annexes (see [Annex A](#) to [Annex E](#)) for the specific type of Ethernet transceiver.

The *S-parameter*  $S_{CC21}$ ,  $S_{DD21}$ ,  $S_{DC21}$  and  $S_{CD21}$  of CMC samples used for testing may be measured or prepared by the manufacturer according to [Annex J](#) and shall be documented in the test report.

## 5.4 Test configuration

### 5.4.1 General configuration for transceiver network

For evaluation of conducted RF emission, RF immunity, impulse immunity and powered ESD characteristic of an Ethernet transceiver in functional operation mode, a minimal Ethernet test network consisting of two Ethernet transceivers of same type shall be used.

For evaluation of radiated RF emission and RF immunity characteristics, one Ethernet transceiver of the test network is defined as *DUT* and the second as Ethernet link partner.

The test configuration, in general consists of Ethernet transceivers with external mandatory components (Ethernet node) in a minimal test network, where filtered power supplies, signals, monitoring probes and coupling networks are connected as shown in [Figure 4](#) for conducted tests and [Figure 5](#) for radiated tests. The definitions for tested BIN differ for different types of Ethernet transceiver and are given in the related annexes (see [Annex A](#) to [Annex F](#)).

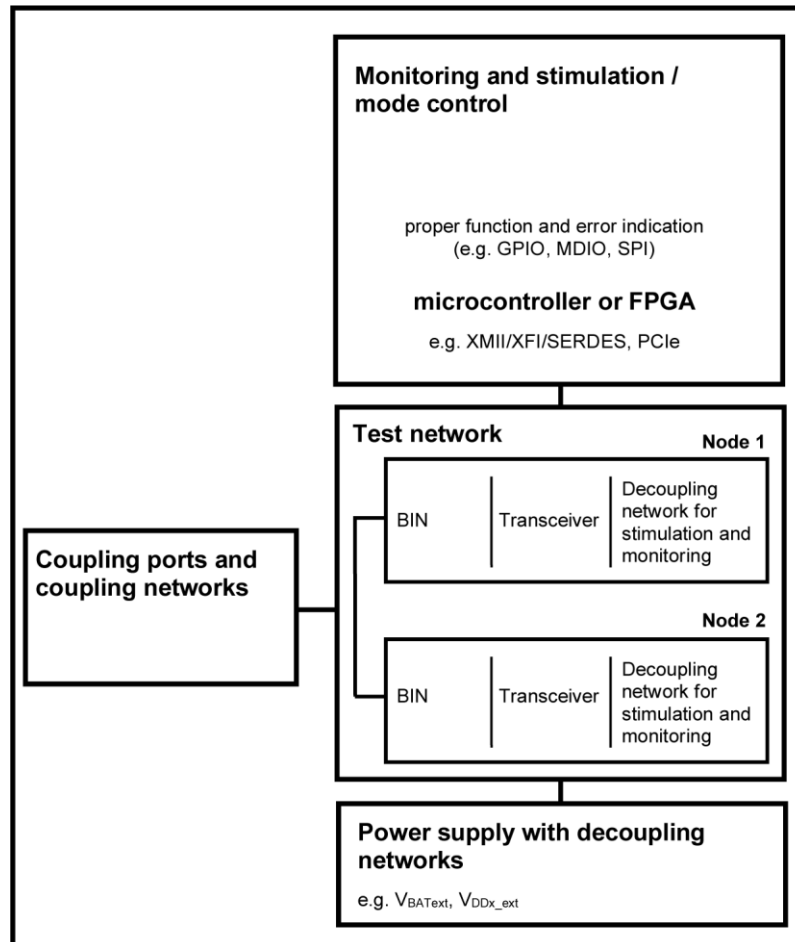


**Figure 4 – General test configuration for tests in transceiver network for conducted tests**

NOTE In specific cases or for analyses, a deviation from this setup can be agreed between the users of this document and will be noted in the test report.

Both the nodes are configured according to the data sheet of the semiconductor manufacturer to establish a full or half duplex Ethernet link (whichever is supported by the Ethernet system). For copper-based Ethernet transceivers, this connection is realised using impedance controlled PCB traces and not a wire connection. For optical Ethernet transceivers this connect is realized by optical fiber.

The microcontroller or FPGA is used for configuring and monitoring the Ethernet transceiver(s) and for generating. The test communication signal. For this purpose, it should be able to operate with the communication interfaces that are supported by the tested Ethernet transceiver (e.g. MII, RGMII, SGMII, XFI/SERDES, PCIe).

If the Ethernet transceivers support multiple MII interfaces, in minimum two of them shall be used for the configuration of the transceiver network. The selection recommendation for each Ethernet transceiver type is given in the corresponding annexes (see Annex A to Annex F). Other MII interfaces e.g. RMII and GMII can be used for testing in addition, if agreed between the users of this standard. The same shall be noted in the test report. Node 1 shall be configured with MII interface type 1 and node 2 with MII interface type 2. If only one interface type is implemented, both nodes are configured with the same available interface (MII or RGMII or SGMII).

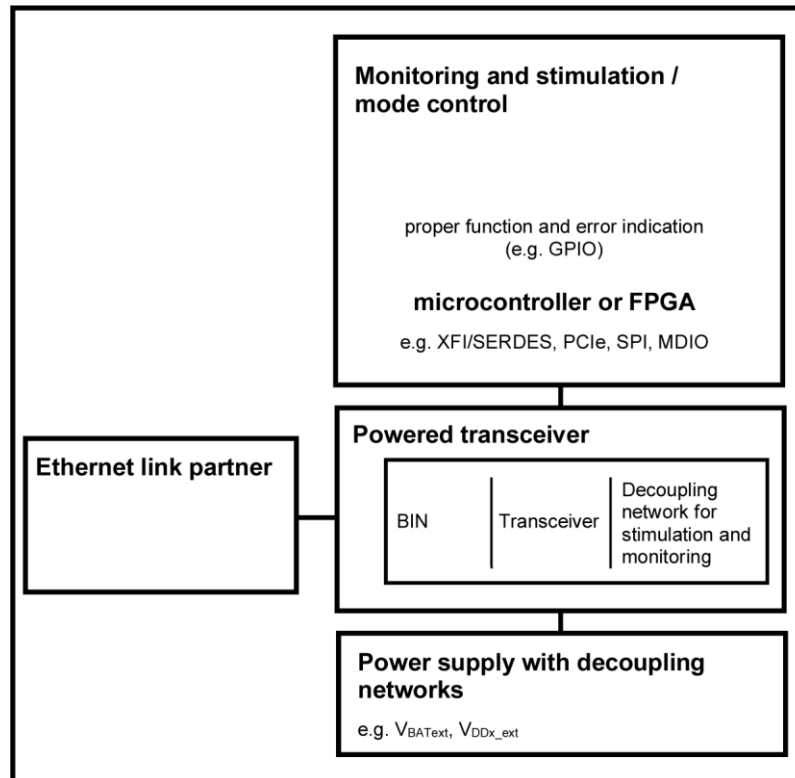


**Figure 5 – General test configuration for tests in transceiver network for radiated tests**

In most cases, it is beneficial to use a microcontroller or [FPGA](#) per Ethernet node. The microcontroller or [FPGA](#) shall be EMC decoupled from the tested transceiver (and its EMC coupling networks) using filter networks on voltage supplies. Specific layout requirements shall be considered. A specific software implementation runs on the microcontroller or [FPGA](#), which should be adapted to the transceiver type, especially for configuration and monitoring.

If an EAS or an IC with more than one integrated Ethernet transceiver (e.g. Dual [PHY](#)) is being evaluated, each port that is intended to be used for wired Ethernet communication shall be tested separately. For that purpose, the tested port of node 1 shall be connected with the same port of node 2 (port 1 to port 1, port 2 to port 2, etc.).

For radiated tests the [MDI](#) connection to the Ethernet link partner should be a single balanced twisted pair cable with a length of 200 ( $\pm 20$ ) mm and its characteristic shall fulfil the definitions of the related Ethernet standard. Multiple external link partner connections of EAS could be limited because of test board constraints. In this case, the Ethernet test links can be realized between different [MDI](#) ports of the EAS itself on the EMC test board but at least one port shall be connected to an external Ethernet link partner.

General drawings of schematics with more details are given in [Annex G](#).

#### 5.4.2 General configuration for single transceiver

The general test configuration for unpowered ESD test of Ethernet transceivers consists of a single Ethernet transceiver with external mandatory components on the test board with discharge coupling networks as shown in [Figure 6](#).

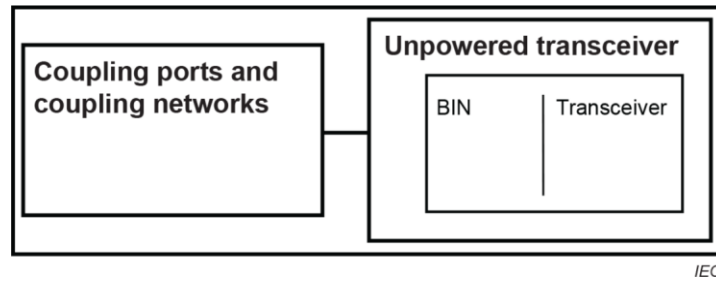
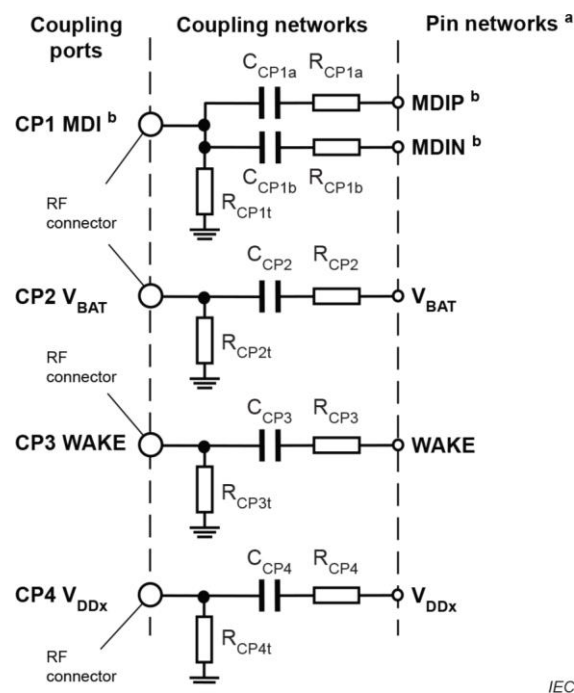


Figure 6 – General test configuration for unpowered ESD test

#### 5.4.3 Transceiver network tests - coupling ports and networks for conducted tests

The coupling ports and coupling networks are used to transfer disturbances to or from the test network with a defined transfer characteristic. The schematic of the coupling ports, networks and pins are shown in Figure 7. The values of the components are dependent on the test method and the tested Ethernet transceiver type and are defined in Table 5 with additional definitions given in the corresponding annexes for the transceiver type (see Annex A to Annex F). The tolerance of the components shall be 1 % or less. For the resistors  $R_{CP1a}$  and  $R_{CP1b}$  used for symmetrical coupling, a maximum mismatch of 0,1 % is recommended.

NOTE Components can be selected by measurement of their value.



#### Key

- <sup>a</sup> The pin networks include all external mandatory components for the respective pin or pins.
- <sup>b</sup> The pins MDIP and MDIN represent all pins of an electrical Ethernet transceiver that are connected to the MDI. For 100BASE-TX transceivers a second MDI coupling network is required for testing the second path of the Ethernet link.

Figure 7 – Transceiver network tests - coupling ports and networks

**Table 5 – Transceiver network tests - component value definitions of coupling ports and networks**

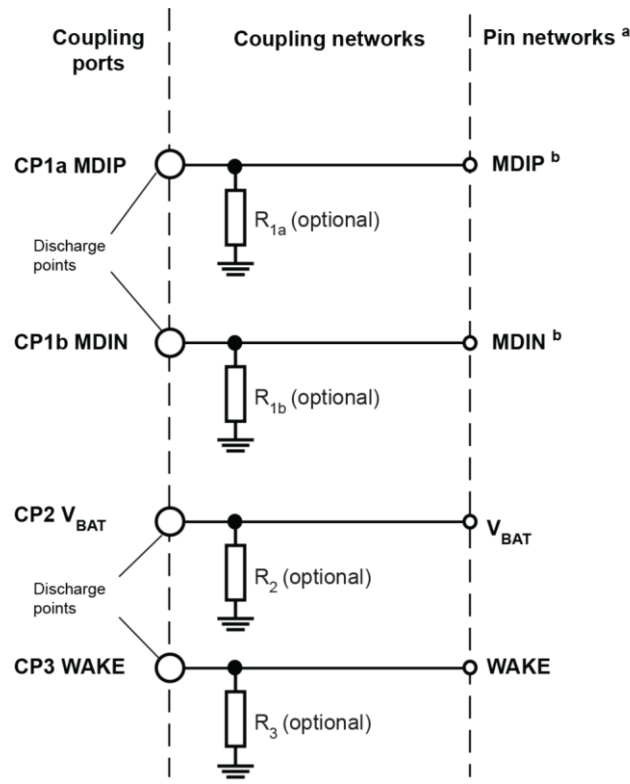
| Port                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Type     | Purpose                                           | Component                                                                                                                                   |                            |                        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|---------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |          |                                                   | $R_{CP1..4}$                                                                                                                                | $C_{CP1..4}$               | $R_{CP1..4t}$          |
| CP1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | EMI1     | RF emission measurement on MDI                    | see definition in corresponding annexes for specific type of Ethernet transceiver (see <a href="#">Annex A</a> to <a href="#">Annex F</a> ) |                            |                        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | RF1      | RF coupling for immunity test on MDI              |                                                                                                                                             |                            |                        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | IMP1     | Impulse coupling on MDI                           |                                                                                                                                             |                            |                        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | ESD1 IND | Indirect ESD coupling on MDIP, MDIN <sup>ab</sup> |                                                                                                                                             |                            |                        |
| CP2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | EMI2     | RF emission measurement on $V_{BAT}$              | $R_{CP2} = 120 \Omega$                                                                                                                      | $C_{CP2} = 6,8 \text{ nF}$ | $R_{CP2t} = 51 \Omega$ |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | RF2      | RF coupling for immunity test on $V_{BAT}$        | $R_{CP2} = 0 \Omega$                                                                                                                        | $C_{CP2} = 6,8 \text{ nF}$ | not used               |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | IMP2     | Impulse coupling on $V_{BAT}$                     | $R_{CP2} = 0 \Omega$                                                                                                                        | Shorted                    | not used               |
| CP3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | EMI3     | RF emission measurement on WAKE                   | $R_{CP3} = 120 \Omega$                                                                                                                      | $C_{CP3} = 6,8 \text{ nF}$ | $R_{CP3t} = 51 \Omega$ |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | RF3      | RF coupling for immunity test on WAKE             | $R_{CP3} = 0 \Omega$                                                                                                                        | $C_{CP3} = 6,8 \text{ nF}$ | not used               |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | IMP3     | Impulse coupling on WAKE                          | $R_{CP3} = 0 \Omega$                                                                                                                        | $C_{CP3} = 1,0 \text{ nF}$ | not used               |
| CP4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | EMI4     | RF emission measurement on $V_{DDX}$              | $R_{CP4} = 120 \Omega$                                                                                                                      | $C_{CP4} = 6,8 \text{ nF}$ | $R_{CP4t} = 51 \Omega$ |
| <p>The parasitic inductance value of all resistors and capacitors used for RF emission and immunity coupling networks shall be less than 2 nH.</p> <p><math>R_{CP1a}</math> and <math>R_{CP1b}</math> can be combined out of two resistors of the same type.</p> <p><sup>a</sup> All used resistors of the ESD coupling network shall be specified as ESD-robust up to the maximum used discharge voltage level. The specified peak voltage of used capacitors shall be at least 3 kV. The value for the coupling capacitance is estimated related to the FCP test setup for indirect ESD test defined in ISO 10605:2023.<sup>b</sup></p> <p><sup>b</sup> The resistor <math>R_{CP1t}</math> is used optional to avoid static pre-charge of discharge point caused by the ESD generator. A spark over at these resistors at high test levels shall be avoided. If a static pre-charge is prevented by the ESD generator's construction, these resistors are not needed. Alternatively, an external resistor can be used to remove pre-charges of each discharge point before each single test.</p> |          |                                                   |                                                                                                                                             |                            |                        |

The test configurations with coupling ports and coupling networks, connected to the Ethernet test network are given in the general drawing of the schematics in [Annex G](#).

The characterisation of the coupling ports and coupling networks is carried out as follows: The magnitude of insertion losses ( $S_{21}$  measurement) between the ports (CP1 to CP4) and the inputs of the respective transceiver pin network on the test board shall be measured and documented in the test report. The connection of signal pads using 50  $\Omega$  coaxial probe directly and ground connection shall be as short as possible. For this characterisation, the coupling port shall be configured for RF immunity or emission testing and the Ethernet transceivers along with the components [BIN](#) shall be removed. All other components, which are directly connected to the coupling port (e.g. filter to power supply or loads) remain on the test board.

#### 5.4.4 Single transceiver tests - coupling ports and networks

The discharge points are connected by the coupling networks to the Ethernet transceiver test circuitry. The schematic and definitions of the coupling ports, networks and pins used for unpowered ESD tests are given in Figure 8 and Table 6.



IEC

Key

- <sup>a</sup> The pin networks include all external mandatory components for the respective pin or pins.
- <sup>b</sup> The pins MDIP and MDIN represent all pins of an electrical Ethernet transceiver that are connected to the MDI. For 100BASE-TX transceivers a second MDI coupling network is required for testing the second path of the Ethernet link.

**Figure 8 – Coupling ports and networks for unpowered ESD tests**

**Table 6 – Definitions of coupling ports for unpowered ESD tests**

| Port                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Type  | Purpose                                 | Components                                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------------------------------|--------------------------------------------------|
| CP1a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | ESD1a | Direct ESD coupling on MDIP             | metal trace for galvanic connection <sup>a</sup> |
| CP1b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | ESD1b | Direct ESD coupling on MDIN             | metal trace for galvanic connection <sup>a</sup> |
| CP2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | ESD2  | Direct ESD coupling on V <sub>BAT</sub> | metal trace for galvanic connection <sup>a</sup> |
| CP3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | ESD3  | Direct ESD coupling on WAKE             | metal trace for galvanic connection <sup>a</sup> |
| <sup>a</sup> The optional resistors R <sub>1a</sub> , R <sub>1b</sub> , R <sub>2</sub> and R <sub>3</sub> with $R \leq 220 \text{ k}\Omega$ are used to avoid static pre-charge of discharge point caused by the ESD generator. A spark over at these resistors at high test levels shall be avoided. If a static pre-charge is prevented by the ESD generator's construction, these resistors are not needed. Alternatively, an external resistor can be used to remove pre-charges of each discharge point before each single test. |       |                                         |                                                  |

## 5.5 Test communication and signals

### 5.5.1 General

Depending on the functionality of the Ethernet transceiver, different test signals are defined for communication in normal operation mode and wake-up from low power mode.

### 5.5.2 Test signals for normal operation mode

A communication test signal shall be used for testing Ethernet transceivers in normal operation mode. The parameters of this periodical signal are defined in [Table 7](#).

**Table 7 – Definition of test communication for normal operation mode**

| Topic              | Content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Test communication | <ul style="list-style-type: none"> <li>– data frame transmission initiated by host controller <ul style="list-style-type: none"> <li>• Ethernet packet (e.g. ISO/IEC/IEEE 8802-3:2017 Ethernet frame, TCP/IP, UDP/IP...) with minimum 1 000 bytes data payload</li> <li>• minimum 80 % bus load</li> <li>• payload data 5A<sub>16</sub></li> </ul> </li> <li>– data frame transmission initiated by Ethernet transceiver itself (optional) <ul style="list-style-type: none"> <li>• activation of internal <a href="#">BIST</a> or <a href="#">PRBS</a> test with maximum possible performance</li> </ul> </li> </ul> |

### 5.5.3 Test signals for low power mode

Tests of unwanted wake-up shall be performed without test a signal.

For wanted wake-up tests in low power mode, depending on the transceiver type, a specific wake-up pulse may be required to initiate the wake-up sequence for the [DUT](#). The definition of the test communication signal in normal mode is then used to check for successful wanted wake-up behaviour. The definitions of the wake-up pulse shall be according to the specifications from the semiconductor manufacturer.

## 5.6 Evaluation criteria

### 5.6.1 General

For immunity performance evaluation of Ethernet transceivers, different evaluation criteria are defined during and after exposure to disturbances.

The resulting functional status of the Ethernet transceiver shall be classified in status classes A<sub>IC</sub>, C<sub>IC</sub> or D<sub>IC</sub> according to IEC 62132-1 following the definitions in [5.6.1](#).

### 5.6.2 Evaluation criteria for functional operation modes

The evaluation criteria for functional operation modes for Ethernet transceivers are defined in [Table 8](#).

For failure monitoring, the evaluation criteria defined in [Table 8](#) shall be used. The failure validation applies to all transceivers in the test network if not otherwise defined. As soon as a transceiver under test violates the evaluation criteria, an error event for this test case is generated. In case of monitoring analog signals, (e.g. [INH](#) output signal) the reference values depend on the transceiver under test and shall be captured in undisturbed conditions before the test. These reference signals combined with the boundary values are used to generate the failure validation masks. Deviations from the defined boundary values can be agreed and shall be noted in the test report.

**Table 8 – Evaluation criteria for Ethernet transceiver**

| Transceiver mode | Purpose                      | Test signal                 |                                              |                                                                                                                                                                                                                                            |
|------------------|------------------------------|-----------------------------|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                  |                              |                             | Function                                     | Activity                                                                                                                                                                                                                                   |
| Normal           | Communication and cross talk | Ethernet test communication | Link                                         | read out of register(s) for link status defined by the semiconductor manufacturer                                                                                                                                                          |
|                  |                              |                             | DTT                                          | error check of all transferred data between the two nodes of the test network by microcontroller or <b>FPGA</b> or<br>error check for <b>BIST</b> or <b>PRBS</b> test for data frame transmission initiated by Ethernet transceiver itself |
|                  |                              |                             | CRC                                          | read out of available register for <b>CRC</b> status <sup>a</sup>                                                                                                                                                                          |
|                  |                              |                             | SQI/SNR                                      | read out and documentation of all available registers for indication of <b>SQI</b> or <b>SNR</b> value <sup>b</sup>                                                                                                                        |
|                  |                              |                             | <b>BIST</b> or <b>PRBS</b> test <sup>c</sup> | read out of available register for status or result of <b>BIST</b> or <b>PRBS</b> tests                                                                                                                                                    |
|                  |                              |                             | other pin functions                          | function validation mask using maximum deviation defined by data sheet (e.g. <b>INH</b> )                                                                                                                                                  |
| Low power mode   | Link up time                 |                             | Link up                                      | measurement of link up time for 100 link up events in presence of disturbances <sup>d</sup>                                                                                                                                                |
|                  | unwanted wake-up             | without                     | wake-up indication                           | function validation mask using maximum deviation defined by data sheet (e.g. <b>INH</b> )                                                                                                                                                  |
|                  | wanted wake-up <sup>e</sup>  | link pulse                  | wake-up indication                           | function validation mask using maximum deviation defined by data sheet (e.g. <b>INH</b> )                                                                                                                                                  |

Different evaluation criteria can be agreed for special cases and shall be noted in the test report.

<sup>a</sup> If no read out of required error registers at the transceiver is possible, the error validation shall be implemented into the microcontroller software in comparable way.

<sup>b</sup> Optional function. Evaluation only if function is implemented.

<sup>c</sup> Optional function. If a **BIST** or **PRBS** test is used instead of a data frame transmission, initiated by host controller, this evaluation replaces the **CRC** and **DTT** function.

<sup>d</sup> Initiation of 100 link up events with check of local and remote receiver status. The maximum allowed link up time for each event is 100 ms. The link up time starts with loading the initialization script for the transceiver and stops after getting the local and remote receiver link up status.

<sup>e</sup> One transceiver (**DUT**) of the test network is configured to operate in low power mode. The second transceiver is configured to operate in normal mode and sends out **WUP** or link pulses to be detected as wake-up by the **DUT**. Only the **DUT** is monitored and shall wake-up at least after 100 ms (see definition in ISO 21111-2:2020).

### 5.6.3 Evaluation criteria in unpowered condition after exposure to disturbances

The input I-V characteristic (current versus voltage) of a pin under test to GND including mandatory components shall be measured using e.g. a semiconductor parameter analyser. If measurements with mandatory components are not applicable, they shall be removed. The test voltage range should cover or exceed the maximum voltage rating of the pin under test up to the level where e.g. break down, snap back or clamping occurs.

NOTE Commonly used test voltages are  $\pm 50$  V to  $\pm 70$  V with test current limitations of  $\pm 0,5$  mA to  $\pm 5$  mA in order to avoid damage of IC during characteristic curve measurement.

Any significant change of I-V characteristic (e.g. more than  $\pm 5$  % of maximum applied test voltage or current) measured before and after the immunity test is considered as a failure. **Figure 9** shows a principle drawing of the maximum deviation on an I-V characteristic.

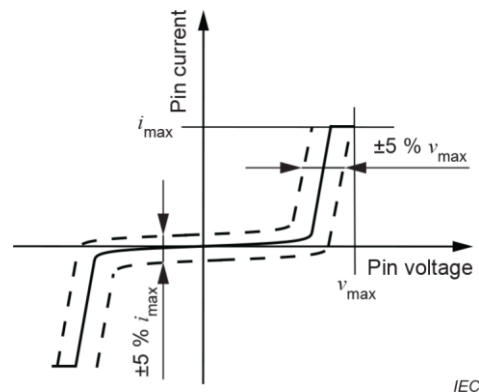


**Figure 9 – Principle drawing of the maximum deviation on an I-V characteristic**

Alternatively, a parameter test according to data sheet of the [DUT](#) can be used as well to verify damages of the IC.

#### 5.6.4 Status classes

The functional status classes for Ethernet transceivers based on the evaluation criteria are defined in [Table 9](#).

**Table 9 – Definition of functional status classes**

| Resulting status class | Requirement                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A <sub>IC</sub>        | <ul style="list-style-type: none"> <li>no error occurred during exposure to disturbance, evaluation criteria of <a href="#">5.6.2</a> for Link, <a href="#">DTT</a>, <a href="#">CRC</a> and other pin functions in normal mode and wake-up indication in low power mode</li> <li>no damage detected after exposure to disturbance, evaluation criteria of <a href="#">5.6.3</a>, that can be checked at the end of all functional tests</li> </ul> |
| A1 <sub>IC</sub>       | <ul style="list-style-type: none"> <li>no error occurred during exposure to disturbance, evaluation criteria of <a href="#">5.6.2</a> for Link</li> </ul>                                                                                                                                                                                                                                                                                           |
| A2 <sub>IC</sub>       | <ul style="list-style-type: none"> <li>no error occurred during exposure to disturbance, evaluation criteria of <a href="#">5.6.2</a> for <a href="#">DTT</a> and <a href="#">CRC</a></li> </ul>                                                                                                                                                                                                                                                    |
| A3 <sub>IC</sub>       | <ul style="list-style-type: none"> <li>no wake-up of the Ethernet transceiver operating in low power mode during exposure to disturbance to disturbance, evaluation criteria of <a href="#">5.6.2</a> for unwanted wake-up</li> </ul>                                                                                                                                                                                                               |
| A4 <sub>IC</sub>       | <ul style="list-style-type: none"> <li>successful wake-up of the Ethernet transceiver operating in low power mode on receiving the <a href="#">WUP</a> or link pulse from the link partner during exposure to disturbance to disturbance, evaluation criteria of <a href="#">5.6.2</a> for wanted wake-up</li> </ul>                                                                                                                                |
| A5 <sub>IC</sub>       | <ul style="list-style-type: none"> <li>no error occurred during exposure to disturbance, evaluation criteria of <a href="#">5.6.2</a> for unwanted wake-up caused by ESD discharges during exposure, proper wake-up functionality and correct change into normal mode on request during exposure</li> </ul>                                                                                                                                         |
| C <sub>IC</sub>        | <ul style="list-style-type: none"> <li>error occurred during exposure to disturbance, evaluation criteria of <a href="#">5.6.2</a></li> <li>no error occurred after exposure to disturbance, evaluation criteria of <a href="#">5.6.2</a>, <a href="#">DUT</a> automatically returns into proper operation</li> <li>no damage detected after exposure to disturbance, evaluation criteria of <a href="#">5.6.3</a></li> </ul>                       |
| D <sub>IC</sub>        | <ul style="list-style-type: none"> <li>error occurred during exposure to disturbance, evaluation criteria of <a href="#">5.6.2</a></li> <li>no error occurred after exposure to disturbance, evaluation criteria of <a href="#">5.6.2</a>, but <a href="#">DUT</a> does not automatically returns into proper operation when</li> </ul>                                                                                                             |

|  |                                                                                                                                                                                                                                                                                                                         |
|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <p>disturbance is removed until a simple operator action (e.g. re-initialization by MDIO or SPI (D1<sub>IC</sub>), power off/on (D2<sub>IC</sub>)) has been done</p> <ul style="list-style-type: none"> <li>– no damage detected after exposure to disturbance, evaluation criteria of <a href="#">5.6.3</a></li> </ul> |
|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## 5.7 DUT specific information

The following information are required for setting up and conducting the EMC tests of Ethernet transceivers and shall be supported by the semiconductor manufacturer:

- test circuit for typical application of transceiver;
- software configuration data for setting up the transceiver in typical application;
- detailed information for data transmission and error register read out activity.

The following additional information should be supported by the semiconductor manufacturer, if available or needed respectively:

- EMC optimized test circuit (optimised [MDI](#) test network and optimized filter or supplier specific filter at voltage supply pins);
- information on recommended ESD protection devices;
- layout application hints or equivalent layout requirements;
- software configuration data for setting up the transceiver in an EMC optimized state.

## 6 Test and measurement

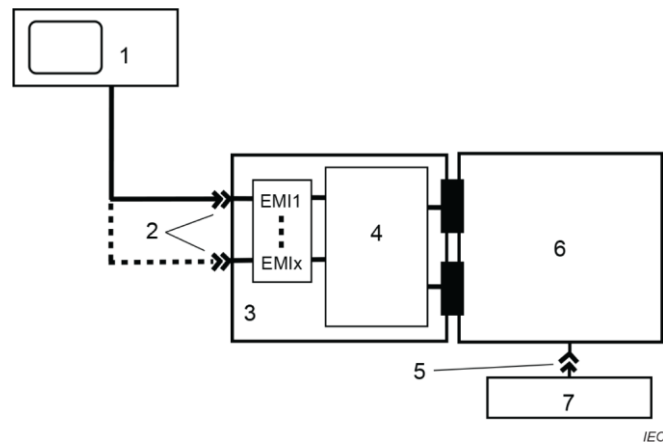
### 6.1 Emission of conducted RF disturbances

#### 6.1.1 Test method

The measurement of the conducted RF emission shall be performed by 150 Ω direct coupling method according to IEC 61967-4.

#### 6.1.2 Test setup

The conducted RF emission measurement of the transceiver shall be carried out using a setup according to [Figure 10](#) with the coupling network as defined in corresponding annexes (see [Annex A](#) to [Annex F](#)) for the tested Ethernet transceiver type.



### Key

- 1 Spectrum analyser / EMI receiver
- 2 Coupling ports (MDI: EMI1,  $V_{BAT}$ : EMI2, WAKE: EMI3,  $V_{DDx}$ : EMIx), coaxial connector
- 3 Test board
- 4 Test network
- 5 Connector
- 6 Host controller board
- 7 Power supply ( $V_{BAText}$ ,  $V_{DDx\_ext}$ , GND)

**Figure 10 – Test setup for measurement of conducted RF disturbances**

The test equipment definitions are the following:

- spectrum analyser / EMI receiver;
- test board;
- host controller board;
- power supply.

### 6.1.3 Test procedure and parameters

The settings of the conducted RF measurement equipment are given in [Table 10](#).

**Table 10 – Settings of the conducted RF measurement equipment**

| RF Measurement equipment           | Spectrum analyser                                         | EMI receiver |
|------------------------------------|-----------------------------------------------------------|--------------|
| Detector                           | Peak                                                      |              |
| Frequency range                    | 0,15 MHz to 2 750 MHz 2 750 MHz to 6 000 MHz <sup>a</sup> |              |
| Resolution bandwidth (RBW)         |                                                           |              |
| 150 kHz to 30 MHz:                 | 10 kHz                                                    | 9 kHz        |
| 30 MHz to 6 000 MHz:               | 100 kHz                                                   | 120 kHz      |
| Video bandwidth (VBW)              | ≥ 3 times RBW                                             | -            |
| Numbers of sweeps                  | 10 (max hold)                                             | -            |
| Measurement time per step          | -                                                         | ≥ 100 ms     |
| Frequency sweep time               | ≥ 100 s                                                   | -            |
| Frequency step width               |                                                           |              |
| 150 kHz to 30 MHz:                 | -                                                         | ≤ 5 kHz      |
| 30 MHz to 6 000 MHz <sup>a</sup> : | -                                                         | ≤ 50 kHz     |

FFT based EMI receivers can be used as well if they meet CISPR 16-1-1 definitions.

<sup>a</sup> depending on pin and transceiver type

The conducted RF emission measurements shall be performed according to the definitions provided in [Annex A](#) to [Annex F](#) that correspond to the specific Ethernet transceiver type.

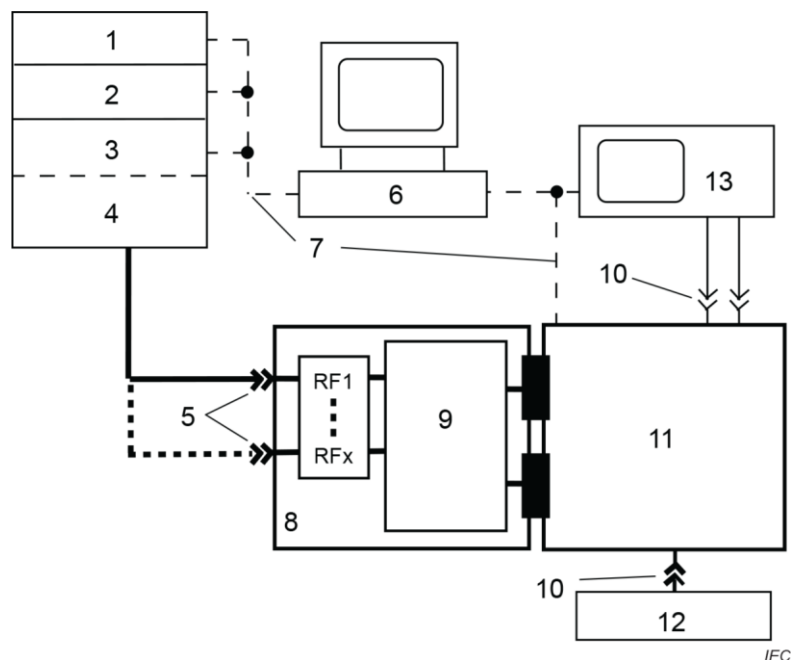
## 6.2 Immunity to conducted RF disturbances

### 6.2.1 Test method

The test of the conducted RF immunity shall be performed by using the [DPI](#) test method according to IEC 62132-4.

### 6.2.2 Test setup

The conducted RF immunity tests of the transceiver shall be carried out using a setup according to [Figure 11](#) with the coupling network as defined in corresponding annexes for the tested Ethernet transceiver type (see [Annex A](#) to [Annex F](#)).



#### Key

- 1 RF generator
- 2 RF amplifier
- 3 RF power meter
- 4 Directional coupler
- 5 Coupling ports (MDI: RF1,  $V_{BAT}$ : RF2, WAKE: RF3), coaxial connector
- 6 Control PC (optional)
- 7 Remote control (optional)
- 8 Test board
- 9 Test network
- 10 Connector
- 11 Host controller board
- 12 Power supply ( $V_{BAText}$ ,  $V_{DDX\_ext}$ , GND)
- 13 DSO

**Figure 11 – Test setup for DPI tests**

The test equipment definitions are the following:

- RF generator;
- RF amplifier (output power  $P \geq 10$  W);
- power meter with directional coupler;
- test board;
- host controller board;
- power supply;
- control PC (optional);
- digital storage oscilloscope (DSO, optional).

### 6.2.3 Test procedure and parameters

To determine the conducted RF immunity of the Ethernet transceiver, tests with the parameters given in [Table 11](#) shall be carried out.

**Table 11 – Specifications for DPI tests**

| Item                                                                     | Parameter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |          |
|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| Frequency                                                                | Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Step     |
|                                                                          | 0,1 MHz to 1 MHz <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0,05 MHz |
|                                                                          | 1 MHz to 10 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0,25 MHz |
|                                                                          | 10 MHz to 100 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1 MHz    |
|                                                                          | 100 MHz to 200 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2 MHz    |
|                                                                          | 200 MHz to 400 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 MHz    |
|                                                                          | 400 MHz to 1 000 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 10 MHz   |
|                                                                          | 1 000 MHz to 2 000 MHz <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 10 MHz   |
|                                                                          | 2 000 MHz to 6 000 MHz <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 20 MHz   |
| Minimum forward power                                                    | 10 dBm (10 mW)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |          |
| Maximum forward power                                                    | 39 dBm (8 W)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |          |
| Power step size                                                          | 0,5 dB                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |          |
| Dwell time                                                               | 1 s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |          |
| Modulation<br>(including optional frequency ranges)                      | $f = 0,1$ MHz to 6 000 MHz: CW<br>$f = 0,1$ MHz to 380 MHz: AM 80 % 1 kHz ( $\hat{P}_{PM} = \hat{P}_{CW}$ )<br>$f = 380$ MHz to 2 700 MHz: PM 1 kHz, ton 500 $\mu$ s ( $\hat{P}_{PM} = \hat{P}_{CW}$ )<br>$f = 2 700$ MHz to 3 100 MHz: PM 300 Hz, ton 3 $\mu$ s ( $\hat{P}_{PM} = \hat{P}_{CW}$ )<br>$f = 3 100$ MHz to 6 000 MHz: PM 1 kHz, ton 500 $\mu$ s ( $\hat{P}_{PM} = \hat{P}_{CW}$ )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |
| Test procedure for evaluation of functional status class A <sub>IC</sub> | <p>Before each single test It shall be ensured that the transceiver is in proper function in relation to function status class A<sub>IC</sub> for the related test case (e.g. Link is established for test of Link error, CRC error or the DUT is set into low power mode for test of unwanted or wanted wake-up).</p> <p>Searching for malfunction in relation to function status classes A1<sub>IC</sub>, A2<sub>IC</sub>, A3<sub>IC</sub> or A4<sub>IC</sub> during the complete dwell time while power is stepwise increased.</p> <p>An optimized control procedure can be used to reduce the test time but ensuring that there are no artifacts in the RF inputs during frequency or power steps.</p> <p>EXAMPLE Procedure for each frequency step:</p> <ul style="list-style-type: none"> <li>– start with maximum forward power or with the level that caused a malfunction at the previous frequency step,</li> </ul> |          |

|                                                                                             |                                                                                                                                                                                                                                                                                                                                                                       |
|---------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                             | <ul style="list-style-type: none"> <li>– in case of malfunction at this power level reduce the power level by 6 dB and repeat the test,</li> <li>– increase the power stepwise until a malfunction occurs or the maximum forward power is reached,</li> <li>– the immunity level at this frequency is the maximum forward power that causes no malfunction</li> </ul> |
| Test procedure for evaluation of functional status class C <sub>IC</sub> or D <sub>IC</sub> | Apply the test power for each frequency step and evaluate the functional status after each test.                                                                                                                                                                                                                                                                      |
| a depending on pin and transceiver type                                                     |                                                                                                                                                                                                                                                                                                                                                                       |

The tests for functional status class A<sub>IC</sub> evaluation shall be performed according to the definition in the Ethernet transceiver type corresponding annexes (see [Annex A](#) to [Annex F](#)). For each test, an immunity threshold curve with the forward power as the parameter shall be determined and documented in a diagram in the test report.

The tests for functional status class C<sub>IC</sub> or D<sub>IC</sub> shall be performed according to the definition provided in [Annex A](#) to [Annex F](#) that correspond to the specific Ethernet transceiver type.

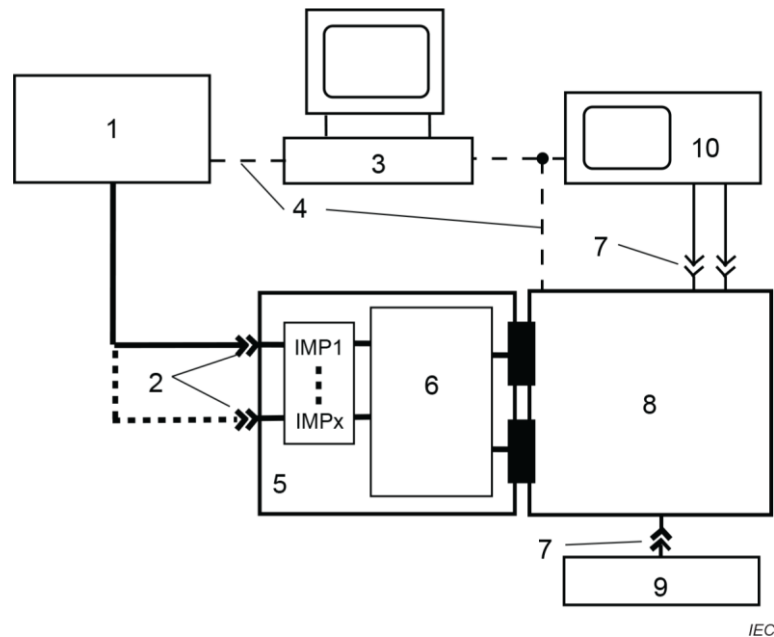
### 6.3 Immunity to impulses

#### 6.3.1 Test method

The test of the impulse immunity shall be performed by using the non-synchronous transient injection method according to IEC 62215-3.

#### 6.3.2 Test setup

The impulse immunity tests of the transceiver shall be carried out using a setup according to [Figure 12](#) with the coupling network as defined in corresponding annexes (see [Annex A](#) to [Annex F](#)) for the tested Ethernet transceiver type.



### Key

- 1 Test pulse generator
- 2 Coupling ports (MDI: IMP1,  $V_{BAT}$ : IMP2, WAKE: IMP3), coaxial connector
- 3 Control PC (optional)
- 4 Remote control (optional)
- 5 Test board
- 6 Test network
- 7 Connector
- 8 Host controller board
- 9 Power supply ( $V_{BAText}$ ,  $V_{DDx\_ext}$ , GND)
- 10 DSO

**Figure 12 – Test setup for impulse immunity tests**

The test equipment definitions are the following:

- test pulse generator (according to ISO 7637-2:2011);
- test board;
- host controller board;
- power supply;
- control PC (optional);
- digital storage oscilloscope (DSO, optional).

### 6.3.3 Test procedure and parameters

To determine the immunity of the transceiver against impulses defined in ISO 7637-2:2011, tests with the definitions and parameters given in [Table 12](#) and [Table 13](#) shall be performed.

**Table 12 – Specifications for impulse immunity tests**

| Item                                           | Definitions and parameters                                                                                                                                                                                                             |
|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Test pulses<br>(see <a href="#">Table 13</a> ) | 1, 2a, 3a, 3b at coupling port IMP2: test pulse generator provides impulses and voltage supply $V_{BAT}$ for DUT<br>3a, 3b, (1, 2a optional) at coupling port IMP1, IMP3: test pulse generator provides impulses but no voltage supply |

|                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|-------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Amplitude step size                                                           | 10 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Dwell time                                                                    | 1 min for tests of functional status class A <sub>IC</sub><br>10 min for tests of functional status class C <sub>IC</sub> or D <sub>IC</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Test procedure for functional status class A <sub>IC</sub>                    | <p>Before each single test it shall be ensured that the transceiver is in proper function in relation to function status class A<sub>IC</sub> for the related test case (e.g. Link is established for test of Link error, CRC error or the DUT is set into low power mode for test of unwanted or wanted wake-up).</p> <p>Searching for malfunction in relation to function status classes A1<sub>IC</sub>, A2<sub>IC</sub>, A3<sub>IC</sub> or A4<sub>IC</sub> during a dwell time of minimum 5 s while pulse amplitude is stepwise increased up to the defined test pulse levels (as e.g. given in ).</p> <p>At the determined maximum voltage the achieved immunity level shall be proved with a dwell time of 1 min.</p> <p>An optimized control procedure can be used to reduce test time.</p> <p>The immunity level is the maximum amplitude that causes no malfunction.</p> |
| Test procedure for functional status class C <sub>IC</sub> or D <sub>IC</sub> | Apply the defined test pulses (as e.g. given in ) and evaluate the functional status after each test.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

**Table 13 – Parameters for impulse immunity test**

| Test pulse <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                 | Maximum pulse amplitude | Pulse repetition frequency | Internal resistance | Remarks                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|----------------------------|---------------------|--------------------------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                         | V <sub>s</sub> max      | (1/t <sub>1</sub> )        | R <sub>i</sub>      |                                            |
|                                                                                                                                                                                                                                                                                                                                                                                                         | V                       | Hz                         | Ω                   |                                            |
| 1                                                                                                                                                                                                                                                                                                                                                                                                       | – 100                   | 2                          | 10                  | battery shall be off only during the pulse |
| 2a                                                                                                                                                                                                                                                                                                                                                                                                      | + 75                    | 2                          | 2                   | -                                          |
| 3a                                                                                                                                                                                                                                                                                                                                                                                                      | – 150                   | 10 000                     | 50                  | -                                          |
| 3b                                                                                                                                                                                                                                                                                                                                                                                                      | + 100                   | 10 000                     | 50                  | -                                          |
| <sup>a</sup> according to ISO 7637-2:2011, pulse amplitudes are defined under open load conditions, parameters for rise time and duration for 12 V- systems are set as default. Other pulse values for target applications in other power domains as e.g. 24 V, 48 V or pulses defined in IEC standards (e.g. IEC 61000-4-4 and IEC 61000-4-5) can be used if required for the transceiver application. |                         |                            |                     |                                            |

The tests for functional status class A<sub>IC</sub> evaluation shall be performed according to the definition provided in [Annex A](#) to [Annex F](#) that correspond to the specific Ethernet transceiver type. For each test an impulse immunity level shall be determined and documented in the test report.

The tests for functional status class C<sub>IC</sub> or D<sub>IC</sub> shall be performed according to the provided in [Annex A](#) to [Annex F](#) that correspond to the specific Ethernet transceiver type.

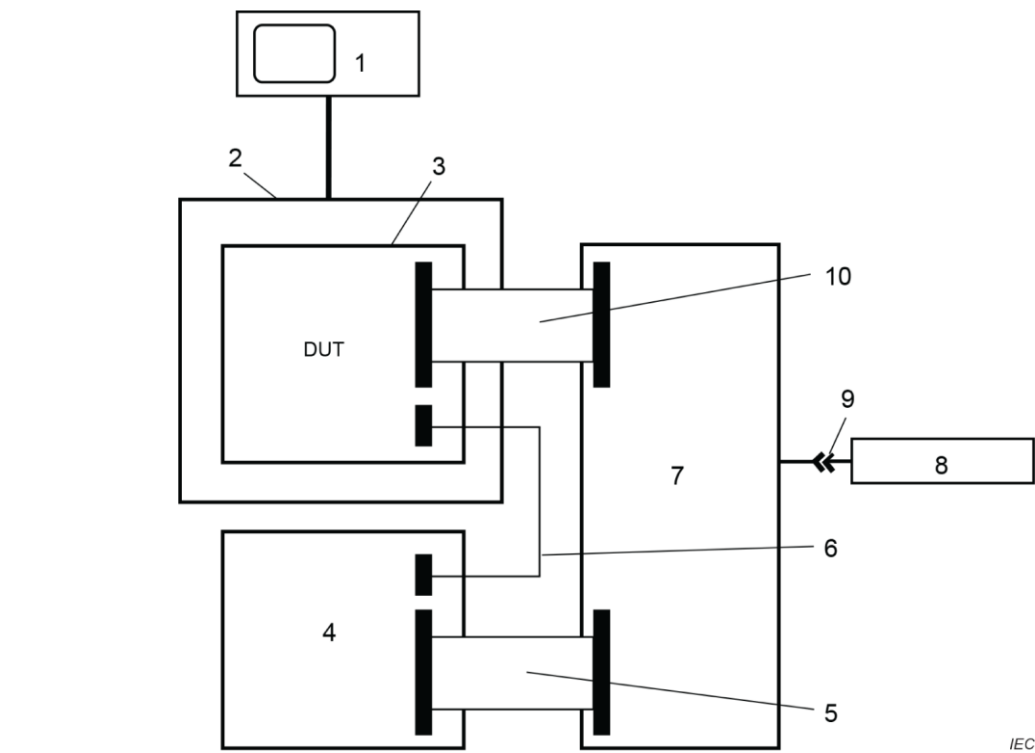
## 6.4 Emission of radiated RF disturbances

### 6.4.1 Test method

The measurement of the radiated RF emission should be performed by IC stripline method according to IEC 61967-8 or by GTEM cell method according to IEC 61967-2.

### 6.4.2 Test setup

The conducted RF emission measurement of the transceiver shall be carried out using a setup according to [Figure 13](#).



Key

- 1 Spectrum analyser / EMI receiver
- 2 IC stripline or GTEM cell
- 3 Test board
- 4 Ethernet link partner
- 5 Interface to link partner
- 6 MDI connection
- 7 Host controller board
- 8 Power supply ( $V_{BAText}$ ,  $V_{DDx\_ext}$ , GND)
- 9 Connector
- 10 Controller interface

Figure 13 – Test setup for measurement of radiated RF emission

The test equipment definitions are the following:

- spectrum analyser / EMI receiver;
- IC stripline including 50  $\Omega$  RF termination resistor for output or GTEM cell;
- test board for radiated RF tests;
- host controller board;
- board with Ethernet link partner (test board as used for conducted RF emission, DPI and transient tests is proposed), and
- power supply.

6.4.3 Test procedure and parameters

The settings of the radiated RF measurement equipment are given in Table 14.

Table 14 – Settings of the radiated RF measurement equipment

| RF Measurement equipment | Spectrum analyser | EMI receiver |
|--------------------------|-------------------|--------------|
| Detector                 | Peak              |              |

|                                                                                    |                                                              |          |
|------------------------------------------------------------------------------------|--------------------------------------------------------------|----------|
| Frequency range                                                                    | 0,15 MHz to 2 750 MHz<br>2 750 MHz to 6 000 MHz <sup>a</sup> |          |
| Resolution bandwidth (RBW)                                                         |                                                              |          |
| 150 kHz to 30 MHz:                                                                 | 10 kHz                                                       | 9 kHz    |
| 30 MHz to 6 000 MHz:                                                               | 100 kHz                                                      | 120 kHz  |
| Video bandwidth (VBW)                                                              | ≥ 3 times RBW                                                | -        |
| Numbers of sweeps                                                                  | 10 (max hold)                                                | -        |
| Measurement time per step                                                          | -                                                            | ≥ 100 ms |
| Frequency sweep time                                                               | ≥ 100 s                                                      | -        |
| Frequency step width                                                               |                                                              |          |
| 150 kHz to 30 MHz:                                                                 | -                                                            | ≤ 5 kHz  |
| 30 MHz to 6 000 MHz:                                                               | -                                                            | ≤ 50 kHz |
| FFT based EMI receivers can be used as well if they meet CISPR 16-1-1 definitions. |                                                              |          |
| <sup>a</sup> depending on transceiver type                                         |                                                              |          |

The radiated RF emission measurements shall be performed according to the definition provided in [Annex A](#) to [Annex F](#) that correspond to the specific Ethernet transceiver type.

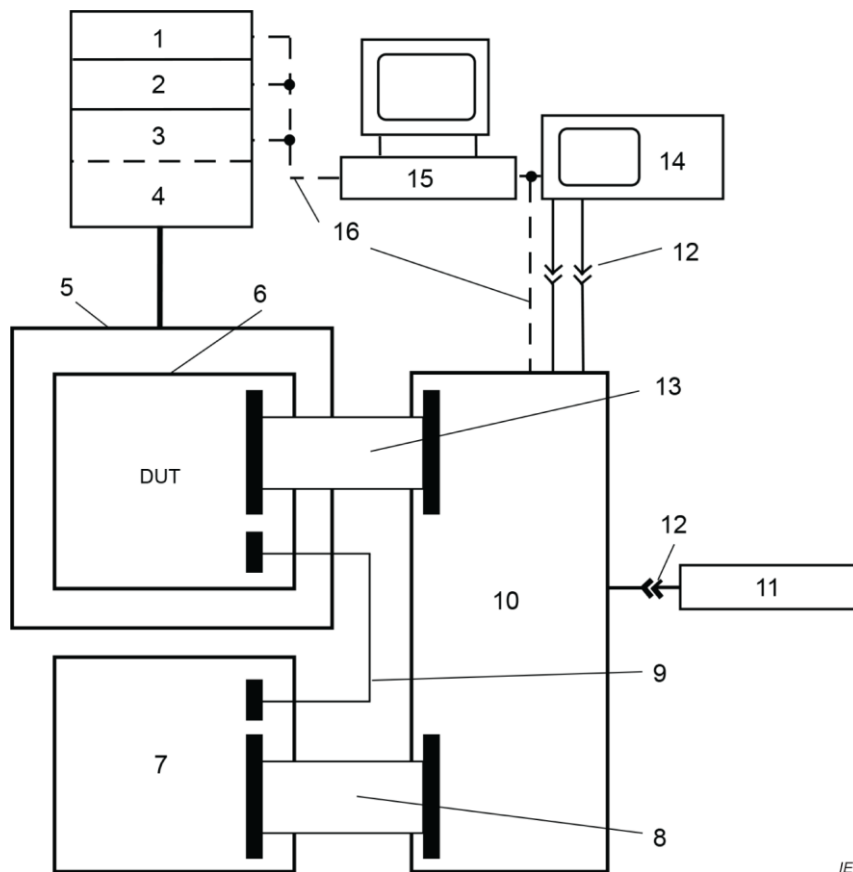
## 6.5 Immunity to radiated RF disturbances

### 6.5.1 Test method

The test of the radiated RF immunity should be performed by IC Stripline method according to IEC 62132-8 or by GTEM cell method according to IEC 62132-2.

### 6.5.2 Test setup

The conducted RF immunity tests of the transceiver shall be carried out using a setup according to [Figure 14](#).



IEC

## Key

- 1 RF generator
- 2 RF amplifier
- 3 RF power meter
- 4 Directional coupler
- 5 IC stripline or GTEM cell
- 6 Test board
- 7 Ethernet link partner
- 8 Interface to link partner
- 9 MDI connection
- 10 Host controller board
- 11 Power supply ( $V_{BAText}$ ,  $V_{DDx\_ext}$ , GND)
- 12 Connector
- 13 Controller interface
- 14 DSO (optional)
- 15 Control PC (optional)
- 16 Remote control (optional)

**Figure 14 – Test setup for radiated RF immunity tests**

The test equipment definitions are the following:

- RF generator;
- RF amplifier;
- power meter with directional coupler;
- IC Stripline including 50  $\Omega$  RF termination resistor for output or GTEM cell;
- test board for radiated RF tests;

- host controller board;
- board with Ethernet link partner (test board as used for conducted RF emission, [DPI](#) and transient tests is proposed);
- power supply;
- control PC (optional);
- digital storage oscilloscope (DSO, optional).

### 6.5.3 Test procedure and parameters

To determine the radiated RF immunity of the Ethernet transceiver, tests with the parameters given in [Table 15](#) shall be carried out.

**Table 15 – Specifications for radiated RF immunity tests**

| Item                                                                     | Parameter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |          |
|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| Frequency                                                                | Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Step     |
|                                                                          | 1 MHz to 10 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 0,25 MHz |
|                                                                          | 10 MHz to 100 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1 MHz    |
|                                                                          | 100 MHz to 200 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2 MHz    |
|                                                                          | 200 MHz to 400 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4 MHz    |
|                                                                          | 400 MHz to 3 000 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 10 MHz   |
|                                                                          | 3 000 MHz to 6 000 MHz <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 20 MHz   |
| Minimum test field strength                                              | 50 V/m                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| Maximum field strength                                                   | 1 000 V/m                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |          |
| Field strength step size                                                 | 50 V/m                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| Dwell time                                                               | 1 s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |
| Modulation (including optional frequency ranges)                         | $f = 1 \text{ MHz to } 6\,000 \text{ MHz: CW}$<br>$f = 1 \text{ MHz to } 380 \text{ MHz: AM } 80 \% \text{ } 1 \text{ kHz } (\hat{P}_{PM} = \hat{P}_{CW})$<br>$f = 380 \text{ MHz to } 2\,700 \text{ MHz: PM } 1 \text{ kHz, ton } 500 \mu\text{s } (\hat{P}_{PM} = \hat{P}_{CW})$<br>$f = 2\,700 \text{ MHz to } 3\,100 \text{ MHz: PM } 300 \text{ Hz, ton } 3 \mu\text{s } (\hat{P}_{PM} = \hat{P}_{CW})$<br>$f = 3\,100 \text{ MHz to } 6\,000 \text{ MHz: PM } 1 \text{ kHz, ton } 500 \mu\text{s } (\hat{P}_{PM} = \hat{P}_{CW})$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |          |
| Test procedure for evaluation of functional status class A <sub>IC</sub> | <p>Before each single test It shall be ensured that the transceiver is in proper function in relation to function status class A<sub>IC</sub> for the related test case (e.g. Link is established for test of Link error, <a href="#">CRC</a> error ).</p> <p>Searching for malfunction in relation to function status classes A1<sub>IC</sub> and A2<sub>IC</sub> during the complete dwell time while test field strength is stepwise increased.</p> <p>An optimized control procedure can be used to reduce the test time but ensuring that there are no artifacts in the <a href="#">DUT</a> response during frequency or test field strength steps.</p> <p>EXAMPLE Procedure for each frequency step:</p> <ul style="list-style-type: none"><li>– start with maximum test value or with the level that caused a malfunction at the previous frequency step,</li><li>– in case of malfunction at this test level reduce the test value by 6dB and repeat the test,</li><li>– increase the test value stepwise until a malfunction occurs or the maximum field strength is reached,</li><li>– the immunity level at this frequency is the maximum field strength that causes no malfunction.</li></ul> |          |
| <sup>a</sup> depending on transceiver type                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |          |

The tests for functional status class  $A_{IC}$  evaluation shall be performed according to the definition provided in [Annex A](#) to [Annex F](#) that correspond to the specific Ethernet transceiver type. For each test, an immunity threshold curve with the forward power as the parameter shall be determined and documented in a diagram in the test report.

## **6.6 Electrostatic Discharge (ESD)**

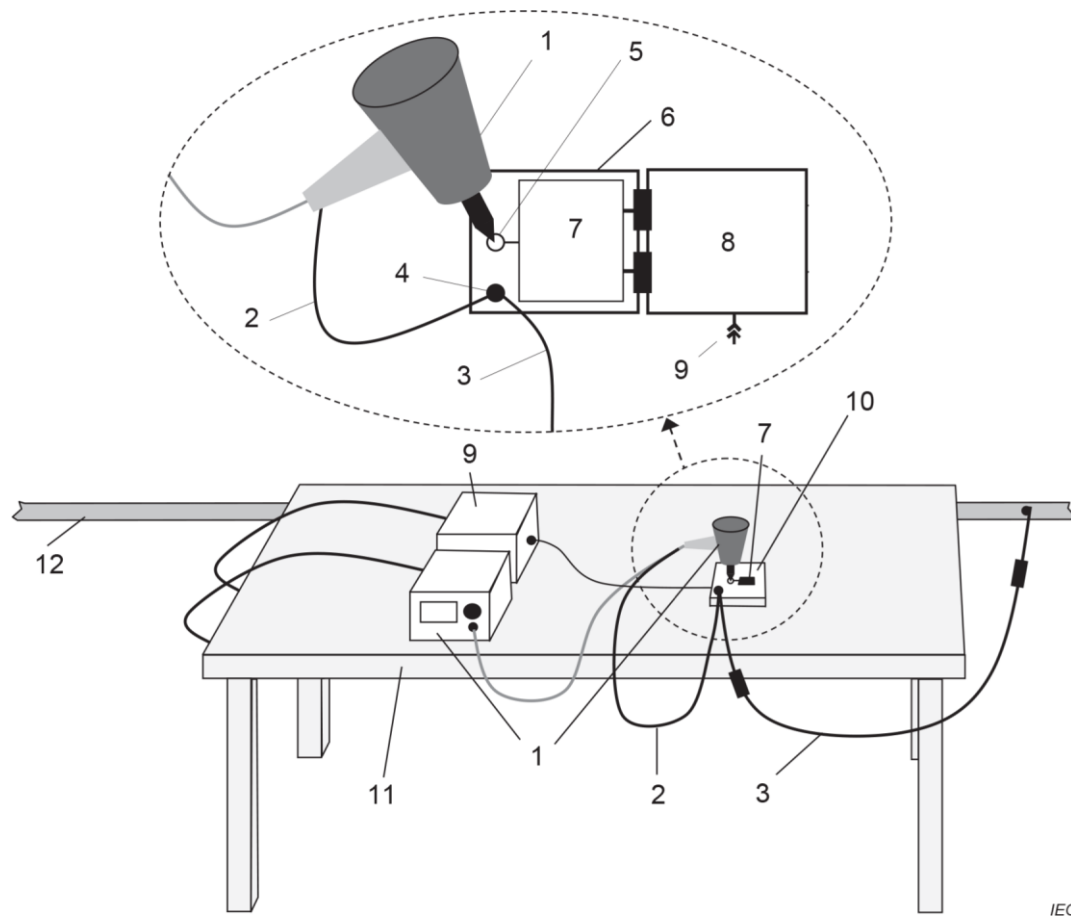
### **6.6.1 Test method**

The ESD immunity test shall be performed in powered and unpowered mode by using the direct discharge method according to ISO 10605:2023.

### **6.6.2 Test setup**

#### **6.6.2.1 Test setup for powered test**

ESD tests in powered mode of the Ethernet transceivers shall be carried out using The test setup according to [Figure 15](#) and [Figure 16](#).



IEC

### Key

- 1 ESD generator
- 2 ESD generator ground return cable
- 3 Connection to protective earth including two 470 kΩ resistors on both ends
- 4 Ground plane connection point of powered ESD test board
- 5 Discharge point
- 6 Powered ESD test board
- 7 Test network
- 8 Host controller board
- 9 Monitoring and stimulation, power supply
- 10 Powered ESD test board with host controller board
- 11 Non-metallic table
- 12 Protective earth

**Figure 15 – Test setup for powered ESD tests - principle arrangement**

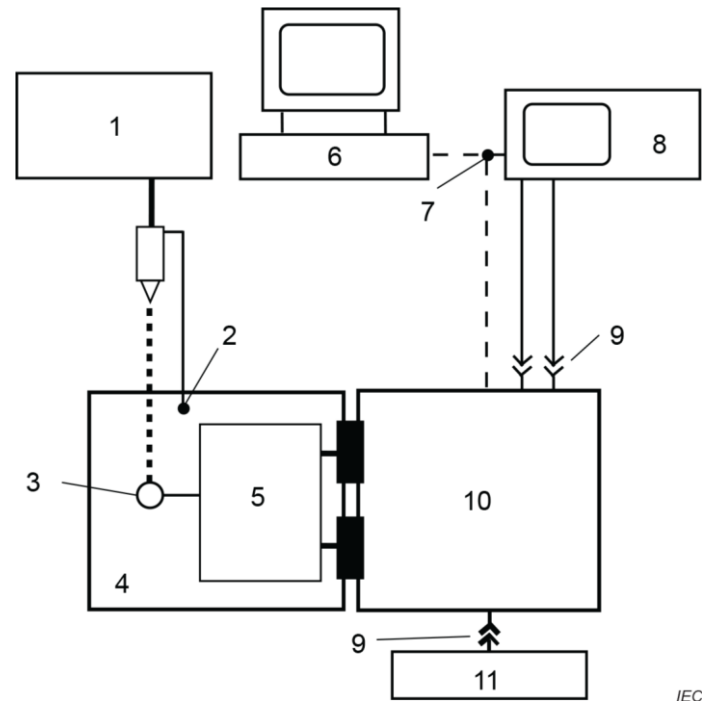
The test equipment definitions for powered ESD tests are the following:

- ESD generator (according to ISO 10605:2023, discharge storage capacitor  $C = 150 \text{ pF}$  and discharge resistor  $R = 330 \text{ } \Omega$ );
- powered ESD test board;
- host controller board;
- auxiliary equipment as power supply, monitoring and stimulation (optional, only needed for tests in powered mode and functional pre/post validation).

The ESD generator ground return cable shall be directly connected to ground plane of the powered ESD test board. This point shall be connected to the protective earth of the electrical

grounding system of the test laboratory. An optional ground plane with a minimum size of 0,5 m × 0,5 m can be used but shall also be connected to the protective earth.

The tip of the ESD generator shall be directly contacted with the discharge point ESD1 IND of the powered ESD test board (described in H.4) for testing.



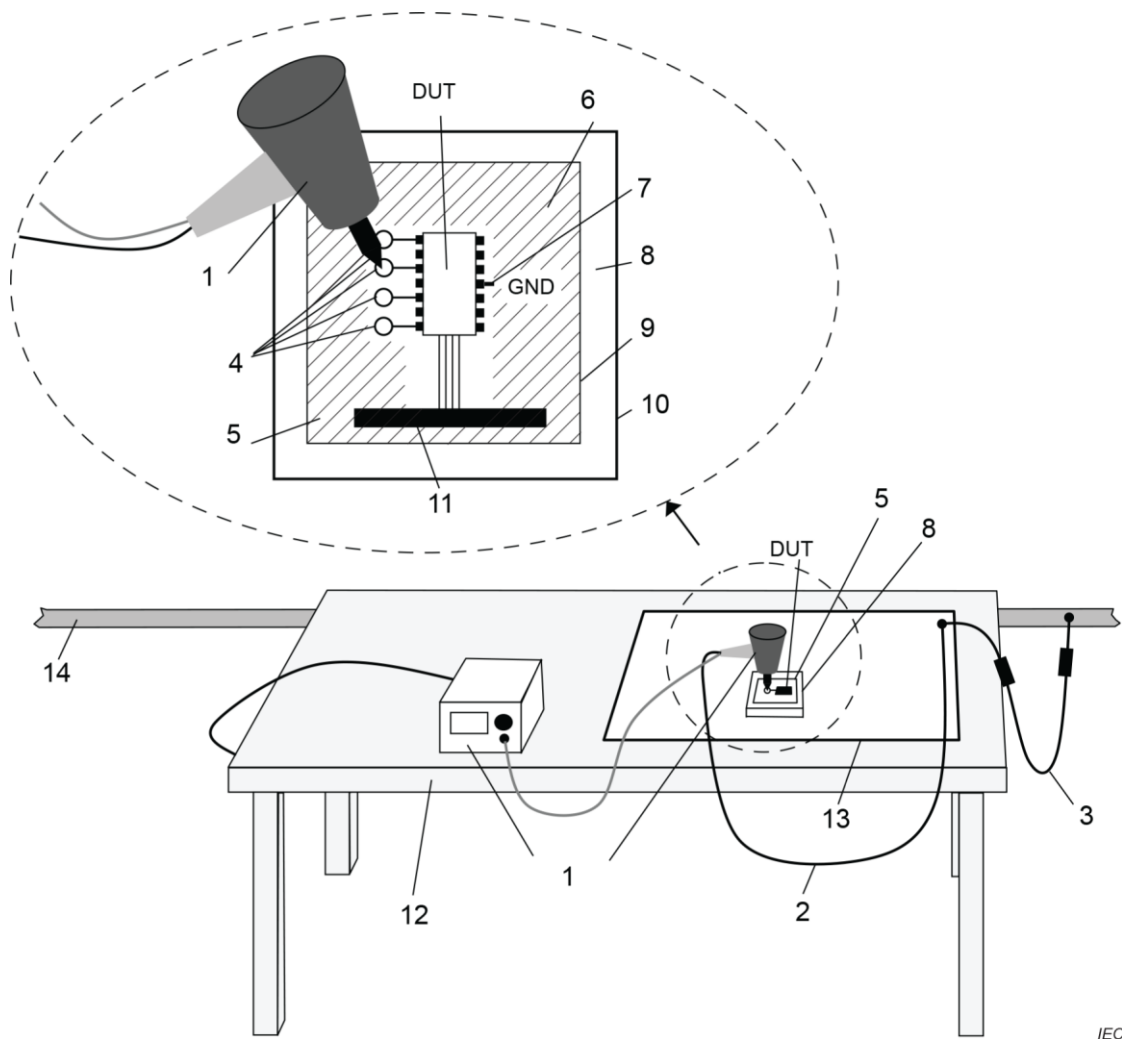
#### Key

- 1 ESD generator
- 2 Ground return connection
- 3 Coupling port (MDI: ESD1 IND)
- 4 Powered ESD test board
- 5 Test network
- 6 Control PC (optional)
- 7 Remote control (optional)
- 8 DSO (optional)
- 9 Connector
- 10 Host controller board
- 11 Power supply ( $V_{BAText}$ ,  $V_{DDx\_ext}$ , GND)

**Figure 16 – Test setup for powered ESD tests - stimulation and monitoring**

#### 6.6.2.2 Test setup for unpowered test

ESD tests in unpowered mode of the Ethernet transceiver shall be carried out using The test setup according to Figure 17 for ESD tests itself and according to Figure 18 for function validation pre and post ESD test.



IEC

### Key

- 1 ESD generator
- 2 ESD generator ground return cable
- 3 Connection to protective earth including two 470 kΩ resistors on both ends
- 4 Discharge points
- 5 ESD test board
- 6 Ground plane of ESD test board
- 7 Connection pin GND to ground plane of ESD test board
- 8 Metallic test fixture
- 9 Surface connection ground plane of ESD test board to metallic test fixture
- 10 Surface connection of metallic test fixture to ground plane
- 11 Connector to monitoring and stimulation
- 12 Non-metallic table
- 13 Ground plane
- 14 Protective earth

**Figure 17 – Test setup for unpowered ESD tests - principle arrangement**

The test equipment definitions for unpowered ESD tests are the following:

- ESD generator (according to ISO 10605:2023, discharge storage capacitor  $C = 150 \text{ pF}$  and discharge resistor  $R = 330 \text{ } \Omega$ );
- ESD test board;

- test fixture;
- ground plane.

The ground plane with a minimum size of 0,5 m × 0,5 m shall be connected to the protective earth of the electrical grounding system of the test laboratory. The ESD generator ground return cable shall be directly connected to this ground plane.