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## Introduction

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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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|                  |                        |
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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.                                       |                                                    |

# DRAFT INTERNATIONAL STANDARD

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ISO/TC 22/SC 32

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## Road vehicles — Connections for on-board electrical wiring harnesses —

Part 6:

### In-vehicle Ethernet, general performance requirements and interface definitions

*Véhicules routiers — Connexions pour faisceaux de câblage électrique embarqués —*

*Partie 6: Ethernet embarqué, exigences générales de performance et définitions d'interface*

ICS: 43.040.10

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# Contents

Page

|                                                                             |            |
|-----------------------------------------------------------------------------|------------|
| Foreword.....                                                               | iv         |
| Introduction.....                                                           | v          |
| <b>1 Scope.....</b>                                                         | <b>1</b>   |
| <b>2 Normative references.....</b>                                          | <b>1</b>   |
| <b>3 Terms and definitions.....</b>                                         | <b>2</b>   |
| 3.1 Terms related to connector properties.....                              | 2          |
| 3.2 Terms related to RF systems and properties.....                         | 2          |
| <b>4 Abbreviated terms.....</b>                                             | <b>3</b>   |
| <b>5 Test and requirements.....</b>                                         | <b>4</b>   |
| <b>6 General.....</b>                                                       | <b>4</b>   |
| 6.1.....                                                                    | 4          |
| 6.1.1 Preconditioning for environmental and mechanical durability.....      | 4          |
| 6.1.2 Test conditions.....                                                  | 4          |
| <b>7 Electromagnetic Environment Classes.....</b>                           | <b>4</b>   |
| <b>8 General electrical definitions and requirements.....</b>               | <b>5</b>   |
| 8.1.1 General setup and measurement fixtures.....                           | 8          |
| 8.1.2 Measurement setups for connectors – UTP connectors.....               | 22         |
| 8.1.3 Measurement setups for connectors – STP connectors.....               | 37         |
| <b>9 MDI (Medium Dependent Interface) Test Head.....</b>                    | <b>59</b>  |
| 9.1 General MDI Test Head Description.....                                  | 59         |
| 9.2 Characterization of MDI Test Head and Limits.....                       | 60         |
| <b>Annex A (informative) In-vehicle Ethernet interface definitions.....</b> | <b>64</b>  |
| <b>Annex B (informative) In-vehicle Ethernet interface definitions.....</b> | <b>82</b>  |
| <b>Annex C (informative) In-vehicle Ethernet interface definitions.....</b> | <b>98</b>  |
| <b>Annex D (informative) In-vehicle Ethernet interface definitions.....</b> | <b>106</b> |
| <b>Annex E (informative) In-vehicle Ethernet interface definitions.....</b> | <b>113</b> |
| <b>Annex F (informative) In-vehicle Ethernet interface definitions.....</b> | <b>120</b> |
| <b>Bibliography.....</b>                                                    | <b>136</b> |

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee [or Project Committee] ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

A list of all parts in the ISO 8092 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

Ethernet is a standard hardware layer protocol, widely used in computer industry. Road vehicles integrate an increasing number of multifunctional modular Ethernet connection systems (for example E-mobility, autonomous driving, camera, radar, body control, driver assistance, multimedia, active safety, etc.).

Building the complete system requires a supply of various components from several different equipment suppliers. Vehicle manufacturers need to define a common specification to ensure that connectors designed and produced for the various equipment suppliers can be mated without any difficulty.

In essence, it affects connections between the harness connector and the electronic control unit.

The connection between the intended device and the harness connector is the only connection that can be standardized and it forms the subject of this document. Due to the location of the device in the vehicle, the connector design could be right or straight.

In general, the Ethernet requirements are specified in ISO/IEC/IEEE 8802-3/2021. The ISO 21111 series of standards provides supplemental specifications (e.g, wake-up, I/O functionality), which are required for in-vehicle Ethernet applications. In road vehicles, Ethernet networks are used for different purposes requiring different bit-rates. Currently, this standard series specifies the 100-Mbit/s and 1-Gbit/s electrical physical layer.

This part of ISO 8092 defines terms and definitions, general performance requirements of a multi-port connection and the interface definition of a single-port, sealed and unsealed connections used with on-board electrical wiring harnesses of road vehicles. The interface definition for the single-port is the basic for multi-port applications.

This part of ISO 8092 also applies to connectors designed to be disconnected after mounting in the vehicle for repair and maintenance purposes.

This part of ISO 8092 is not applicable to internal connections of electronic devices.

With the Evolvement of Automotive Ethernet, there is a need to standardize and specify applicable components, respectively connectors. Targeted wiring options include unshielded twisted pair and shielded twisted pair with the need for different speed grades and bandwidth.

Nevertheless, and with different limits valid for different speed grades, the general purpose of this document is to verify performance requirement and interface connectors with defined test setups, measurement equipment (settings) and test fixtures.

The following [table 1.1](#) indicate the suggested specification purpose. [Table 1.2](#) summarizes interfaces in [ANNEX A](#) to [F](#). They are not normative, but informative.

**Table 1.1 — Related standards applied in ISO**

| Standards     |           | UTP                         |              | semi shielded<br>STP Class1 | fully shielded<br>STP Class 2 |
|---------------|-----------|-----------------------------|--------------|-----------------------------|-------------------------------|
| IEEE802.3     |           | 100BASE-T1                  | 1000BASE-T1  | 1000BASE-T1                 | 1000BASE-T1                   |
| Open Alliance |           | [3] TC2 / [4] TC9           | [4] TC9      | [5] TC9                     | [5] TC9                       |
| ISO           | Channel   | ISO 21111-8                 | ISO 21111-12 | ISO 21111-13                |                               |
|               | Connector | ISO 8092-6<br>(ISO 21111-8) | ISO 8092-6   | ISO 8092-6                  | ISO 8092-6                    |
|               | Cable     | ISO 19642-12                | ISO 19642-12 | (ISO 19642-13)              | (ISO 19642-13)                |

Further Explanation on ISO 21111-8:

We should try to harmonize testmatrices, setups, methods etc...and use TC9 and therefore ISO 8092-6 for all connector qualification purposes. If customer wants to use STP Class 1 and Class 2 for 100BASE-T1 he actually cannot use ISO 21111-8 setups because it does not have STP setups. Result: he should use 1000BASE-T1 STP measurement setups and apply requirement limit values of ISO 21111-8.

**Table 1.2 — Overview of the interfaces shown in the appendices**

|                                                           | 100BASE-T1 | 1000BASE-T1 | unsealed | sealed |
|-----------------------------------------------------------|------------|-------------|----------|--------|
| Annex A                                                   | X*         | X           | X        | X      |
| Annex B                                                   | X*         | X           | X        | X      |
| Annex C                                                   | X*         | X           | X        | X      |
| Annex D                                                   | X*         | X           | X        |        |
| Annex E                                                   | X          |             | X        |        |
| Annex F                                                   | X*         | X           | X        | X      |
| * if 1000BASE-T1 is set, 100BASE-T1 automatically covered |            |             |          |        |

# Road vehicles — Connections for on-board electrical wiring harnesses —

## Part 6:

# In-vehicle Ethernet, general performance requirements and interface definitions

## 1 Scope

This document defines the general minimum specifications of single-port and multi-port connection interfaces, linking the in-vehicle Ethernet devices and harness connectors built into a road vehicle. The test method and requirement are defined in the document. Definition of the interface is described as informative, which is limited to the representation of the single-port connection.

## 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.

ISO 8015, *Geometrical product specifications (GPS) - Fundamentals - Concepts, principles and rules*

ISO 8092-2, *Road vehicles — Connections for on-board electrical wiring harnesses — Part 2: Definitions, test methods and general performance requirements*

ISO 14405, *Geometrical product specifications (GPS) - Dimensional tolerancing*.

ISO 16750-1, *Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 1: General*

ISO 19642, *Road vehicles — Automotive cables. (Under development)*

ISO 19642-12, *Road vehicles — Automotive cables — Part 12: Unscreened paired or quad RF cables with a specified analog bandwidth up to 1 GHz. (Under development)*

ISO 21111, *Road Vehicle — In-vehicle Ethernet*.

ISO 21111-8, *Road Vehicle — In-vehicle Ethernet — Part 8: Electrical 100-Mbit/s Ethernet transmission media, components and tests*

IEC 62153-4-7, 2015, *Metallic communication cable test methods – Part 4-7: Electromagnetic compatibility (EMC) – Test method for measuring of transfer impedance Z<sub>T</sub> and screening attenuation a<sub>S</sub> or coupling attenuation a<sub>C</sub> of connectors and assemblies up to and above 3 GHz – Triaxial tube in tube method*

IEC 62153-4, 9:2018, *Metallic communication cable test methods – Part 4-9: Electromagnetic compatibility (EMC) – Coupling attenuation of screened balanced cables, triaxial method*

EN 50289-1-7:2001, *Communication cables – Specifications for test methods – Part 1-7: Electrical test methods; Velocity of propagation*

EN 61935-1:2010, *Specification for the testing of balanced and coaxial information technology cabling – Part 1: Installed balanced cabling as specified in the standards series EN 50173 (IEC 61935-1:2009, modified)*

IEEE P370, *Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50 GHz*

ISO/IEC/IEEE 8802-3/2021, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet*.

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8092-2 and the following apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

#### 3.1 Terms related to connector properties

##### 3.1.1 housing

housing for inserting the terminal and providing insulation between terminals

##### 3.1.2 cable attachment

any permanent junction of cable to terminal

Note 1 to entry: Crimp and weld are typical methods

Note 2 to entry: Terms related to cables ISO 19642-1

##### 3.1.3 connector

assembly of terminal, housing and related parts that terminate cable for the purpose of providing connection and disconnection to a suitable mating connector

##### 3.1.4 connector coding

mechanical feature to provide differentiation, preventing mating of connectors not intended to be mated

##### 3.1.5 single-port

signifies one Ethernet-port composed by 2 ways (pins or terminals)

##### 3.1.6 multi-port

signifies more than one Ethernet-port arranged inside one housing

#### 3.2 Terms related to RF systems and properties

##### 3.2.1 100BASE-T1 Ethernet

standardized in IEEE 8802.3, the physical layer applies to a single balanced twisted pair cable capable of transmitting 100 Mbit/s up to 15 m in total length

**3.2.2****1000BASE-T1 Ethernet**

standardized in IEEE 8802.3, the physical layer applies to a single balanced twisted pair cable capable of transmitting 1 000 Mbit/s up to 15 m (segment A) or 40 m (segment B) in total length.

**4 Abbreviated terms**

|             |                                                                   |
|-------------|-------------------------------------------------------------------|
| AACRF       | alien attenuation to crosstalk ratio far-end                      |
| AFEXT       | alien far end crosstalk loss                                      |
| AFEXTDC     | alien far end cross conversion loss common to differential        |
| AFEXTDS     | alien far end cross conversion loss single ended to differential  |
| ANEXT       | alien near end crosstalk loss                                     |
| ANEXTDC     | alien near end cross conversion loss common to differential       |
| ANEXTDS     | alien near end cross conversion loss single ended to differential |
| CIDM        | characteristic impedance differential mode                        |
| DUT         | device under test                                                 |
| ECU         | electronic control unit                                           |
| ES          | environment system                                                |
| IL          | insertion loss                                                    |
| LCL         | longitudinal conversion loss                                      |
| LCTL        | longitudinal conversion transmission loss                         |
| MDI         | media dependent interface                                         |
| PCB         | printed circuit board                                             |
| PSANEXT     | power sum alien far end crosstalk loss                            |
| PSAACRF     | power sum power-sum alien attenuation to crosstalk ratio far-end  |
| PSAFEXT     | power sum alien far end crosstalk                                 |
| RL          | return loss                                                       |
| RT          | room temperature                                                  |
| SMA         | sub miniature type A                                              |
| SCC         | standalone communication channel                                  |
| S-Parameter | scattering parameter                                              |
| STP         | acronym for shielded twisted pair                                 |
| TDR         | time domain reflectometry                                         |
| UTP         | unshielded twisted pair cable without jacket                      |

VNA                      vector network analyser

## 5 Test and requirements

## 6 General

### 6.1

#### 6.1.1 Preconditioning for environmental and mechanical durability

All test samples shall be preconditioned at standard ambient temperature ( $23 \pm 5$ ) °C and (25 – 75) % relative humidity for 24 h before the start of any test sequence.

[SOURCE: ISO 16750-1]

#### 6.1.2 Test conditions

All tests shall be carried out at a standard ambient temperature of ( $23 \pm 5$ ) °C and (25–75) % relative humidity unless otherwise stated in the test procedure. This is referred to as room temperature (RT).

Cable in compliance with applicable part of ISO 19642 is recommended. The cable or cables used shall be noted in the test report.

Cable attachment shall be performed in accordance with the terminal manufacturer's specifications, or as agreed between customer and supplier.

When the length of cable is not specified, 500 mm shall be used. When the cable length tolerance is not specified, it shall be  $\pm 10$  mm.

Care shall be taken so that test samples do not influence each other (e.g., in a heat chamber).

Each connector shall have the full complement of terminals fitted unless otherwise specified.

The terminals and connectors used in the test shall be fully assembled unless otherwise specified.

## 7 Electromagnetic Environment Classes

Channels using UTP cabling rely on balance to provide decoupling between the differential data signal and common mode interference. Certain electromagnetic environments (e.g. cabling close to antennas) may demand additional requirements beyond what was specified for UTP channels as in Claus 97 of ISO/IEC/IEEE 8802-3/2021 and in<sup>[4]</sup> and<sup>[5]</sup> of OPEN Alliance.

STP channels shall provide additional EMC margin, taking benefit of combined unbalance attenuation and screening attenuation to an effective coupling attenuation. Adding shielding also reduces common mode interference emissions. The common mode may be emitted by the PHY or caused by unbalance of components along the channel that convert the wanted differential signal power spectrum into unwanted common mode interference.

The amount of additional EMC margin, i.e. the degree of shielding and coupling attenuation, may depend on the specific implementation in the vehicle. Two electromagnetic environment classes are defined to provide most flexibility for choosing suitable components. STP class 1 relies on lower mode conversion allowing simpler shielding while STP class 2 requires full shielding. The coupling and screening attenuation limits for STP class 1 are more relaxed compared to STP class 2. The selection of the appropriate limit class depends on the specific application in the vehicle and is not subject of this specification.

8 General electrical definitions and requirements

All definitions for communication channel, cables and connectors are valid for any temperature, intended to use in application and standard atmosphere condition based on ISO 16750-1. Measurements are generally carried out at room temperature unless specified differently in Section 4.1.

Figure 1 define the port numbering for a multi-port connector, corresponding to the S-parameter port numbering in Table 3.

Figure 1 shows the multiport connector

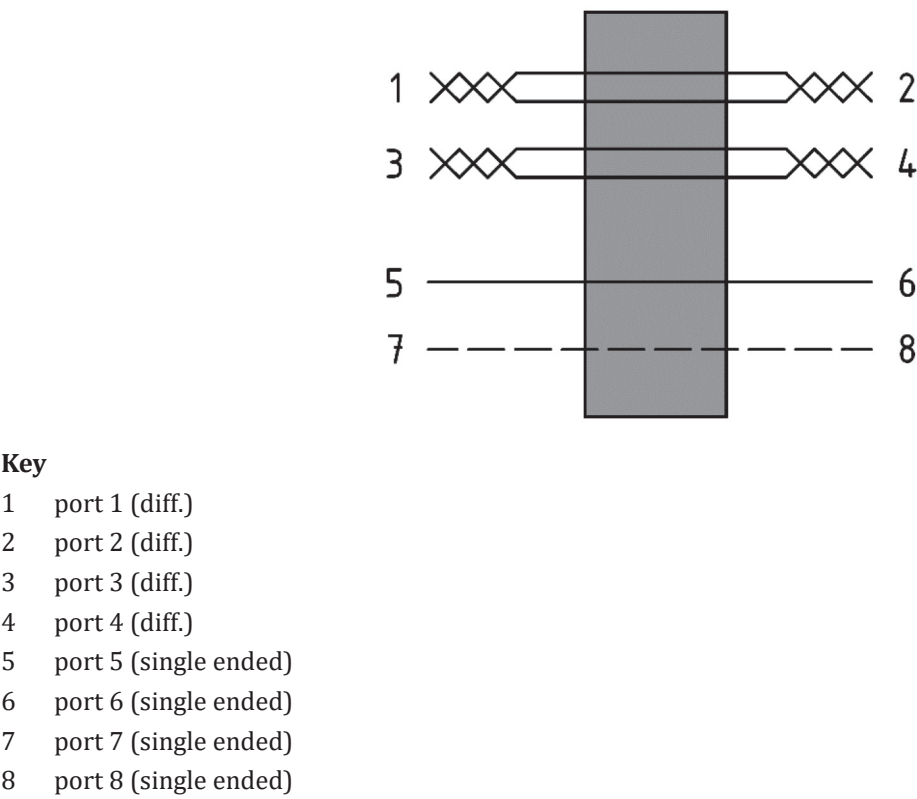


Figure 1 — Typical definition of S-Parameter ports for connectors

For the qualification purpose of connectors used for Ethernet, the following RF requirements are defined as set of the RF-and S-Parameters:

Table 3 — Definitions for RF and S- Parameter

| Test Parameters                                                                    | Symbol or related S-Parameter | Description                                                                      |
|------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------|
| <b>Impedance</b>                                                                   |                               |                                                                                  |
| CIDM                                                                               | $Z_{RF}$                      | Characteristic Impedance Differential Mode (TDR Measurement)                     |
| <b>Single Channel Characteristics (e.g. Port 1,2)</b>                              |                               |                                                                                  |
| Propagation Delay                                                                  | $t_d$                         | Propagation Delay i.e. phase delay according to EN 50289-1-7, see equation (3.5) |
| RL                                                                                 | $S_{dd11}, S_{dd22}$          | Return Loss                                                                      |
| IL                                                                                 | $S_{dd21}$                    | Insertion Loss                                                                   |
| LCL                                                                                | $S_{dc11}, S_{dc22}$          | Longitudinal Conversion Loss                                                     |
| LCTL                                                                               | $S_{dc12}, S_{dc21}$          | Longitudinal Conversion Transfer Loss                                            |
| <b>Cross Talk and Cross Conversion to Neighbour Channels and / or Signal Lines</b> |                               |                                                                                  |
| ANEXT                                                                              | $S_{dd31}, S_{ddy1x}$         | Alien Near End Cross Talk Loss                                                   |
| AFEXT                                                                              | $S_{dd41}, S_{ddy4x}$         | Alien Far End Cross Talk Loss                                                    |
| PSANEXT                                                                            | see equation (3.1)            | Power Sum Alien Near End Cross Talk Loss                                         |
| PSAFEXT                                                                            | see equation (3.2)            | Power Sum Alien Far End Cross Talk Loss                                          |
| PSAACRF                                                                            | see equation (3.3)            | Power Sum Attenuation to Alien Cross Talk Loss Ratio Far End                     |
| ANEXTDC                                                                            | $S_{dc31}, S_{dcyx}$          | Alien Near End Cross Conversion Loss Common to Differential                      |
| ANEXTDS                                                                            | $S_{ds35}, S_{dsyx}$          | Alien Near End Cross Conversion Loss Single-ended to Differential                |
| AFEXTDC                                                                            | $S_{dc41}, S_{dcyx}$          | Alien Far End Cross Conversion Loss Common to Differential                       |
| AFEXTDS                                                                            | $S_{ds45}, S_{dsyx}$          | Alien Far End Cross Conversion Loss Single-ended to Differential                 |
| <b>Single Channel Characteristics (e.g. Port 1,2)</b>                              |                               |                                                                                  |
| Coupling Attenuation                                                               | $a_c$ , see equation (3-6)    | Coupling attenuation                                                             |
| Screening Attenuation                                                              | $a_s$ , see equation (3-7)    | Screening attenuation                                                            |

The following equations can be used to calculate the power-sum crosstalk of connectors and wiring harness.

PSANEXT for a disturbed signal N can be calculated for every port by means of the following equation:

$$PSANEXT(f)_N = -10 \log_{10} \sum_{j=1}^m 10^{\frac{-ANEXT(f)_{Nj}}{10}} \quad (3-1)$$

where the function  $ANEXT(f)_{Nj}$  represents the magnitude (in dB) of the ANEXT loss at frequency  $f$  of the disturbing signal  $j$  (1 to  $m$  of the relevant disturbing neighbour signals) for the disturbed signal  $N$ .

PSAFEXT for a disturbed signal  $N$  can be calculated for every port by means of the following equation:

$$PSAFEXT(f)_N = -10 \log_{10} \sum_{j=1}^m 10^{\frac{-AFEXT(f)_{Nj}}{10}} \quad (3-2)$$

where the function  $AFEXT(f)_{Nj}$  represents the magnitude (in dB) of the AFEXT loss at frequency  $f$  of the disturbing signal  $j$  (1 to  $m$  of the relevant disturbing neighbour signals) for the disturbed signal  $N$ .

PSAACRF for a disturbed signal  $N$  can be calculated for every port by means of the following equation:

$$PSAACRF(f)_N = -10 \log_{10} \sum_{j=1}^m 10^{\frac{-AACRF(f)_{Nj}}{10}} \quad (3-3)$$

where the function  $AACRF(f)_{Nj}$  represents the magnitude (in dB) of the AACRF at frequency  $f$  of the disturbing signal  $j$  (1 to  $m$  of the relevant disturbing neighbour signals) for the disturbed signal  $N$ . The AACRF is calculated by the difference of the AFEXT loss and the insertion loss magnitudes (in dB) of the disturbing link by the following equation:

$$AACRF(f)_{Nj} = AFEXT(f)_{Nj} - IL(f)_N \quad (3-4)$$

The propagation delay is defined as the phase delay of the transmitted signal. It can be calculated from the expanded phase angle of the  $S_{dd21}$  parameter by equation (3-5) as described in EN 50289 1-7.

$$t_d = -\text{Phase}(S_{dd21}) / (360 \cdot f) \text{ in Hz, } t_d \text{ in s, phase angle in degree} \quad (3-5)$$

The coupling attenuation  $a_c$  of the device under test is calculated by equation (3-6) as follows as described in IEC 62153-4-7 and IEC 62153-4-9.

$$a_c = a_{m,min} + 4,77 \quad (3-6)$$

where

- $a_c$  is the coupling attenuation related to the normalized radiating impedance of 150  $\Omega$  in dB;
- $a_{m,min}$  is the attenuation recorded as minimum envelope curve of the measured values in dB;
- 4,77 is the correction factor for a CIDM of 100  $\Omega$  of the device under derived from the formula  $10 \times \log_{10} \left| \frac{300 \Omega}{100 \Omega} \right|$  in dB.

The screening attenuation  $a_s$  of the device under test is calculated by equation (3-7) as described in IEC 62153-4-7 and IEC 62153-4-9. 3-port measurement setup using VNA without balun shall be used with the differential feeding port set to excite in common mode.

$$a_s = a_{m,min} + 10 \times \log_{10} \left| \frac{300 \Omega}{Z_1} \right| \quad (3-7)$$

where

- $a_s$  is the screening attenuation related to the normalized radiating impedance of 150  $\Omega$  in dB;
- $a_{m,min}$  is the attenuation recorded as minimum envelope curve of the measured values in dB;
- $Z_1$  is the characteristic impedance common mode of the cable under test in  $\Omega$ . It is recommended to use TDR equipment for determining this value.

The bandwidth settings for different windows can be calculated for every port by means of the following equation (3-8):

$$\beta = \frac{k}{t_{rise}} \quad (3-8)$$

where

$\beta$  is the bandwidth in GHz;

$t_{rise}$  is the rise time (10 – 90) % in nsec;

$k$  is the Factor;

### 8.1.1 General setup and measurement fixtures

#### 8.1.1.1 Required measurement equipment

For all measurements, a vector network analyzer (VNA) and a TDR measurement system in combination with a test fixture and specific additional arrangements such as a test tube apparatus with the following parameters shall be used:

Table 4 — Required measurement equipment

| Parameter                                      | Equipment           | Parameter                                                                                                                                                                                                                                                                                                                                                                                    | Value                                                                                                                                                                              |
|------------------------------------------------|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Mixed Mode S-parameter                         | VNA                 | Type                                                                                                                                                                                                                                                                                                                                                                                         | 4- port vector network analyzer                                                                                                                                                    |
|                                                |                     | Port reference impedance                                                                                                                                                                                                                                                                                                                                                                     | 50 $\Omega$ single ended                                                                                                                                                           |
|                                                |                     | Frequency range                                                                                                                                                                                                                                                                                                                                                                              | UTP:<br>f = 300 kHz to 1000 MHz<br>STP:<br>f = 1 MHz to 2000 MHz                                                                                                                   |
| Characteristic Impedance (CIDM)                | TDR test system     | Type                                                                                                                                                                                                                                                                                                                                                                                         | 2 channel differential mode                                                                                                                                                        |
|                                                |                     | Port reference impedance                                                                                                                                                                                                                                                                                                                                                                     | 50 $\Omega$ single ended / 100 $\Omega$ differential mode                                                                                                                          |
|                                                |                     | Rise time                                                                                                                                                                                                                                                                                                                                                                                    | Pulse generator: $\leq 25$ ps internal ( $\leq 50$ ps at measurement fixture)<br>Rise time needs to be adjustable to the required values (50ps / 500ps)<br>All values 10 % to 90 % |
| Coupling Attenuation and Screening Attenuation | VNA                 | Type                                                                                                                                                                                                                                                                                                                                                                                         | 3- port vector network analyzer                                                                                                                                                    |
|                                                |                     | Port reference impedance                                                                                                                                                                                                                                                                                                                                                                     | 50 $\Omega$ single ended                                                                                                                                                           |
|                                                |                     | Frequency range                                                                                                                                                                                                                                                                                                                                                                              | f = 1MHz to 1000 MHz                                                                                                                                                               |
|                                                | Test Tube apparatus | Metallic non ferromagnetic triaxial test tube arrangement according to IEC 62153-4-7 with lengths as specified in 4.3.3.3 with inner extension tube of variable length (tube in tube). The test tube diameter depends on the geometric dimension of the DUT. If there are no DUT specific restrictions, a diameter of 40 mm is recommended. Commercially available tube devices can be used. |                                                                                                                                                                                    |
| All                                            | Measurement fixture | Depending on the used test standard (see special definitions for cables and connectors)                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                    |

Time Domain based measurement devices may also be used to measure mixed mode S-parameters if they can translate to the VNA settings in [Table 5](#) and fulfill the calibration accuracy requirements in [Table 7](#) and [8](#).

VNAs may also be used to perform impedance measurements, normally performed with a TDR test system if it can provide an equivalent pulse with 50 / 500 ps rise time as specified in [Table 4](#). In this case, the requirement for 25 ps internally and 50 ps at the measurement fixture does not apply. The measurement should be carried out with the VNA settings given in Table 9.1 and shall be documented in the test report.

#### 8.1.1.2 Vector network analyzer (VNA) settings

To assure a high degree of reliability for transmission measurements, the following precautions are required (EN 61935-1: 2010, Specification for the testing of balanced and coaxial information

technology cabling – Part 1: Installed balanced cabling as specified in the standards series EN 50173 [IEC 61935-1:2009, modified])

1. The reference plane of the calibration shall coincide with the measurement reference plane. In case of differences, the magnitude of errors shall be determined and the measurement fixture parameters shall be characterized to meet the requirements in Section 4.3.1.4.
2. Accurate and consistent resistor loads shall be used for each pair throughout the test sequence.
3. The cable shall be placed to satisfy the requirements for the single tests and needs to be fixed throughout the test sequence.
4. Cable and adapter stresses, as caused by physical flexing, sharp bends and restraints shall be avoided before, during and after the tests. Test cables and adapters shall be selected for high phase stability to meet the requirements in Section 4.3.1.4 during the complete test sequences including handling operation for connecting and disconnecting the DUTs.
5. Test cables, i.e. coaxial cables between measurement devices and measurement fixtures, shall be chosen in a way that the calibration requirements in [Table 7](#) and [8](#) are fulfilled.
6. Overload conditions of the network analyzer shall be avoided.
7. The VNA shall provide enough stability and low drift to ensure to meet the accuracy requirements in [Table 7/8](#) during the entire test sequence.

To achieve high degree of comparability of test results the VNA settings given in [Table 5](#) are recommended. The used VNA setting for each parameter of [Table 5](#) shall be documented in the test report.

**Table 5 — Recommended VNA settings**

| Parameter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Value (UTP)                                                                                         | Value (STP) class 1                                                                              |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Sweep $f_{\text{Start}}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 300 kHz                                                                                             | 1 MHz                                                                                            |
| Sweep $f_{\text{Stop}}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1 GHz                                                                                               | 1 GHz                                                                                            |
| Sweep type                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Logarithmic                                                                                         | Linear                                                                                           |
| Sweep points                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 600                                                                                               | 1 600                                                                                            |
| Output power                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | minimum -10 dBm                                                                                     | minimum -10 dBm                                                                                  |
| Measurement bandwidth                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | $\leq 500$ Hz                                                                                       | $\leq 500$ Hz                                                                                    |
| Port reference impedance differential mode <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 100 $\Omega$                                                                                        | 100 $\Omega$                                                                                     |
| Port reference impedance common mode <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 25 $\Omega$ for connector measurements and MDI Test Head<br>200 $\Omega$ for all other measurements | 25 $\Omega$                                                                                      |
| Data calibration kit (VNA)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Use an appropriate calibration kit. (The calibration kit shall be identified in the test report)    | Use an appropriate calibration kit. (The calibration kit shall be identified in the test report) |
| Averaging function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Single time measurement <sup>a</sup>                                                                | Single time measurement <sup>a</sup>                                                             |
| Smoothing function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Deactivated                                                                                         | Deactivated                                                                                      |
| <sup>a</sup> Multiple averaging setting may be used with recording the actual averaging time used.<br><sup>b</sup> The single ended 4-port S-parameters are captured with 50 $\Omega$ port reference impedances. This results in 100 $\Omega$ differential mode and 25 $\Omega$ common mode port reference impedances after transforming the single ended S-parameters to the mixed mode S-parameters. The mixed mode S-parameters can be converted or re-normalized to the port reference impedances required in <a href="#">Table 5</a> by using the VNA's post processing capabilities or by alternative post processing software. The term "port reference impedance" is also known as "logic port impedance" depending on the equipment or software type. |                                                                                                     |                                                                                                  |

To measure STP connectors, the required de-embedding functionality can be provided by the VNA itself or equivalent post-processing software. The VNA settings shall be chosen as specified by the software or equipment providers. [Table 6.1](#) gives an example.

**Table 6.1 — Recommended VNA settings for de-embedding**

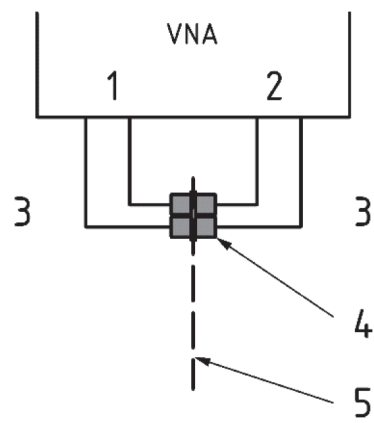
| Parameter                                                                                                                                                                                    | Value                                                                                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Sweep $f_{\text{Start}}$                                                                                                                                                                     | 1 MHz                                                                                            |
| Sweep $f_{\text{Stop}}$                                                                                                                                                                      | $\geq 2$ GHz                                                                                     |
| Sweep type                                                                                                                                                                                   | Linear                                                                                           |
| Sweep points                                                                                                                                                                                 | $\geq 2\ 000$                                                                                    |
| Output power                                                                                                                                                                                 | Minimum -10 dBm                                                                                  |
| Measurement bandwidth                                                                                                                                                                        | $\leq 3$ kHz                                                                                     |
| Port reference impedance differential mode                                                                                                                                                   | 100 $\Omega$                                                                                     |
| Port reference impedance common mode                                                                                                                                                         | 25 $\Omega$                                                                                      |
| Data calibration kit (VNA)                                                                                                                                                                   | Use an appropriate calibration kit. (The calibration kit shall be identified in the test report) |
| Averaging function                                                                                                                                                                           | Single time measurement <sup>a</sup>                                                             |
| Smoothing function                                                                                                                                                                           | Deactivated                                                                                      |
| Filtering for TDR functions                                                                                                                                                                  | Hann window or similar window <sup>b</sup>                                                       |
| <sup>a</sup> Multiple averaging setting may be used with recording the actual averaging time used.                                                                                           |                                                                                                  |
| <sup>b</sup> The window function type has relation to the recommended stop frequency in the table above. This stop frequency needs to be adjusted if an alternative window function is used. |                                                                                                  |

**Table 6.2 — Bandwidth<sup>a</sup> and rise time<sup>b</sup> settings for different windows**

| Window function                                                                                                                                                                             | Factor (k) | Bandwidth ( $\beta$ ) for 500 psec |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------------------------|
| Hamming                                                                                                                                                                                     | 0,912      | 1,824 GHz                          |
| Hann                                                                                                                                                                                        | 0,97       | 1,940 GHz                          |
| Kaiser (Beta 6)                                                                                                                                                                             | 0,99       | 1,980 GHz                          |
| Bartlett                                                                                                                                                                                    | 1,03       | 2,060 GHz                          |
| Blackman                                                                                                                                                                                    | 1,19       | 2,380 GHz                          |
| <sup>a</sup> The bandwidth is stop frequency of the sweep which is used for the measurement.                                                                                                |            |                                    |
| <sup>b</sup> The rise time is the interval of time between the instants at which the instantaneous value of a pulse first reaches a specified lower value and then a specified upper value. |            |                                    |

The VNA calibration accuracy shall be verified by measuring the mode conversion and return loss parameters for a direct thru-thru connection between the balanced ports at the calibration plane ([Figure 2](#)). A pair of high precision matching female-female adaptors is recommended to be used to connect the test cables.

[Figure 2](#) shows the VNA calibration accuracy



- Key**
- 1 diff. port 1
  - 2 diff. port 2
  - 3 coax
  - 4 thru connections
  - 5 calibration reference plane

Figure 2 — Thru-thru connection for verification of VNA calibration accuracy

The LCL, LCTL and RL parameters shall comply with the requirements given in Table 7 for UTP Channel and components. The LCL calibration accuracy may also be verified with measurement cables in open condition at the calibration plane.

Table 7 — VNA calibration accuracy requirements for UTP class

| Test Parameter |                                              | Requirement                                                                                                                                                                                                                                    |
|----------------|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| RL             | $S_{dd11}, S_{dd22}$                         | $\geq \begin{cases} 44 & 1 \leq f < 75 \\ 26 - 20 \log_{10} \left( \frac{f}{600} \right) & 75 \leq f \leq 600 \end{cases} dB$<br>$1 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 200 $\Omega$ (CM) |
| LCL<br>LCTL    | $S_{dc11}, S_{dc22}$<br>$S_{dc21}, S_{dc12}$ | $\geq \begin{cases} 61 & 10 \leq f \leq 80 \\ 83 - 11,51 \log_{10}(f) & 80 < f \leq 600 \end{cases} dB$<br>$10 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 200 $\Omega$ (CM)                      |

*This limits may be exempted for 100BASE-T1*

The LCL, LCTL and RL parameters shall comply with the requirements given in Table 8 for STP Channel and components. The LCL calibration accuracy may also be verified with measurement cables in open condition at the calibration plane.

Table 8 — VNA calibration accuracy requirements for STP class 1

| Test Parameter |                                              | Requirement                                                                                                                                                                   |
|----------------|----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| RL             | $S_{dd11}, S_{dd22}$                         | $\geq \begin{cases} 36 & 1 \leq f < 190 \\ 26 - 20 \log_{10} \left( \frac{f}{600} \right) & 190 \leq f \leq 600 \end{cases} dB$<br>$1 \leq f \leq 600$ , frequency $f$ in MHz |
| LCL<br>LCTL    | $S_{dc11}, S_{dc22}$<br>$S_{dc21}, S_{dc12}$ | $\geq \begin{cases} 56 & 10 \leq f \leq 50 \\ 81,2 - 14,83 \log_{10}(f) & 50 < f \leq 600 \end{cases} dB$<br>$10 \leq f \leq 600$ , frequency $f$ in MHz                      |

Figure 3a and 3b shows the return loss requirement for VNA calibration accuracy UTP and STP class 1

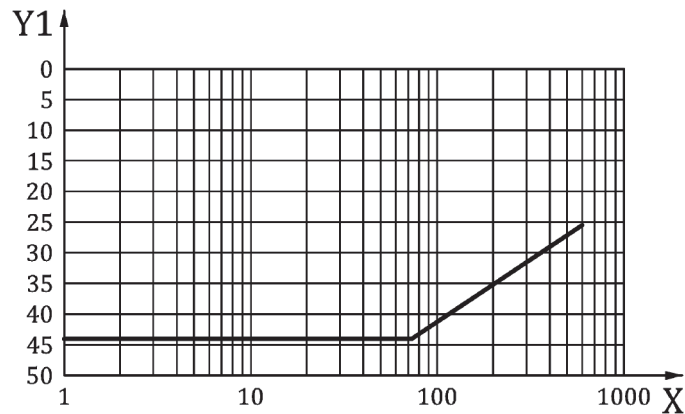


Figure 3a — Return loss requirement for VNA calibration accuracy UTP

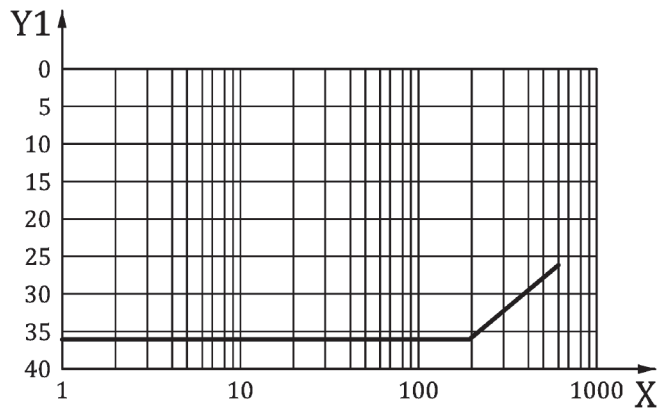


Figure 3b — Return loss requirement for VNA calibration accuracy STP class 1

Figure 3c and 3d shows the LCL/LCTL loss requirement for VNA calibration accuracy UTP and STP class 1

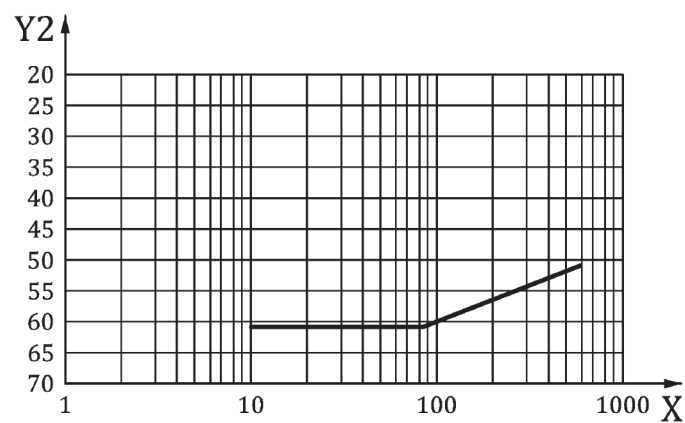
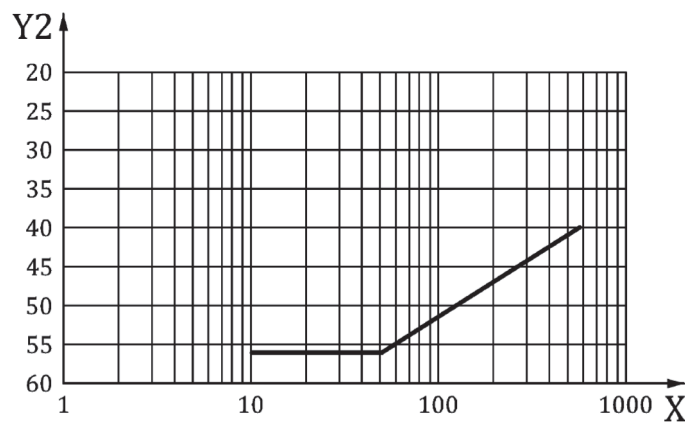


Figure 3c — LCL/LCTL loss requirement for VNA calibration accuracy UTP



**Key**  
X frequency (MHz)  
Y1 return loss (dB)  
Y2 mode conversion loss (dB)

Figure 3d — LCL/LCTL loss requirement for VNA calibration accuracy STP class 1

If impedance measurements are carried out with VNA the following settings are recommended to ensure equivalent results to a TDR based measurement.

Table 9.1 — Recommended VNA settings for impedance measurements

| Parameter                                                                                                                                                                                    | Value                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|
| Sweep $f_{\text{Start}}$                                                                                                                                                                     | 1 MHz, (10 MHz) <sup>a</sup>               |
| Sweep $f_{\text{Stop}}$                                                                                                                                                                      | 2 GHz, (20 GHz) <sup>a</sup>               |
| Sweep type                                                                                                                                                                                   | Linear                                     |
| Sweep points                                                                                                                                                                                 | 2 000                                      |
| Filtering                                                                                                                                                                                    | Hann window or similar window <sup>c</sup> |
| <sup>a</sup> Values in brackets are suitable for characterization of test fixtures (Chapter 4.3.1.4.1) and MDI test heads (Chapter 5.2).                                                     |                                            |
| <sup>b</sup> Multiple averaging setting may be used with recording the actual averaging time used.                                                                                           |                                            |
| <sup>c</sup> The window function type has relation to the recommended stop frequency in the table above. This stop frequency needs to be adjusted if an alternative window function is used. |                                            |

**Table 9.1 (continued)**

| Parameter                                                                                                                                                                                                                                                                                                                                                                                                                                      | Value                                                                                                                                                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| TDR Type                                                                                                                                                                                                                                                                                                                                                                                                                                       | Step                                                                                                                                                     |
| Output power                                                                                                                                                                                                                                                                                                                                                                                                                                   | minimum -10 dBm                                                                                                                                          |
| Measurement bandwidth                                                                                                                                                                                                                                                                                                                                                                                                                          | $\leq 500$ Hz for UTP ( $\leq 3$ kHz for STP class 1 or 2)                                                                                               |
| Port reference impedances                                                                                                                                                                                                                                                                                                                                                                                                                      | 50 $\Omega$ single ended port impedances (This results in 100 $\Omega$ differential mode reference impedance after conversion to mixed mode parameters.) |
| Data calibration kit (VNA)                                                                                                                                                                                                                                                                                                                                                                                                                     | Use an appropriate calibration kit. (The calibration kit shall be identified in the test report)                                                         |
| Averaging function                                                                                                                                                                                                                                                                                                                                                                                                                             | Single time measurement <sup>b</sup>                                                                                                                     |
| Smoothing function                                                                                                                                                                                                                                                                                                                                                                                                                             | deactivated                                                                                                                                              |
| <sup>a</sup> Values in brackets are suitable for characterization of test fixtures (Chapter 4.3.1.4.1) and MDI test heads (Chapter 5.2).<br><sup>b</sup> Multiple averaging setting may be used with recording the actual averaging time used.<br><sup>c</sup> The window function type has relation to the recommended stop frequency in the table above. This stop frequency needs to be adjusted if an alternative window function is used. |                                                                                                                                                          |

**Table 9.2 — Bandwidth<sup>a</sup> and rise time<sup>b</sup> settings for different windows**

| Window function                                                                                                                                                                                                                                                                             | Factor (k) | Bandwidth ( $\beta$ ) for 500 psec |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------------------------|
| Hamming                                                                                                                                                                                                                                                                                     | 0,912      | 1,824 GHz                          |
| Hann                                                                                                                                                                                                                                                                                        | 0,97       | 1,940 GHz                          |
| Kaiser (Beta 6)                                                                                                                                                                                                                                                                             | 0,99       | 1,980 GHz                          |
| Bartlett                                                                                                                                                                                                                                                                                    | 1,03       | 2,060 GHz                          |
| Blackman                                                                                                                                                                                                                                                                                    | 1,19       | 2,380 GHz                          |
| <sup>a</sup> The bandwidth is stop frequency of the sweep which is used for the measurement.<br><sup>b</sup> The rise time is the interval of time between the instants at which the instantaneous value of a pulse first reaches a specified lower value and then a specified upper value. |            |                                    |

To achieve high degree of comparability of test results, the VNA settings given in [Table 10](#) are recommended for coupling attenuation measurements. The used VNA setting for each parameter of [Table 10](#) shall be documented in the test report.

**Table 10 — Recommended VNA settings for coupling and screening attenuation measurements**

| Parameter                                                                                          | Value                                                                                            |
|----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Sweep $f_{\text{Start}}$                                                                           | 1 MHz                                                                                            |
| Sweep $f_{\text{Stop}}$                                                                            | 1 GHz                                                                                            |
| Sweep type                                                                                         | Linear                                                                                           |
| Sweep points                                                                                       | 1 000                                                                                            |
| Output power                                                                                       | minimum -10 dBm                                                                                  |
| Measurement bandwidth                                                                              | $\leq 1$ kHz                                                                                     |
| Port reference impedance differential mode                                                         | 100 $\Omega$                                                                                     |
| Port reference impedance common mode                                                               | 25 $\Omega$                                                                                      |
| Data calibration kit (VNA)                                                                         | Use an appropriate calibration kit. (The calibration kit shall be identified in the test report) |
| Averaging function                                                                                 | Single time measurement <sup>a</sup>                                                             |
| <sup>a</sup> Multiple averaging setting may be used with recording the actual averaging time used. |                                                                                                  |

**Table 10** (continued)

| Parameter                                                                                          | Value       |
|----------------------------------------------------------------------------------------------------|-------------|
| Smoothing function                                                                                 | deactivated |
| <sup>a</sup> Multiple averaging setting may be used with recording the actual averaging time used. |             |

### 8.1.1.3 Presentation of measurement results

Test results shall be documented in the following way:

- Documentation of test conditions (e.g. humidity, temperature, cable length)
- Documentation of cable types and production number (also for S-parameter and coupling attenuation measurements of connectors)
- Documentation of used calibration kit and of calibration accuracy in thru-thru configuration
- Pictures of test set-up and measurement fixture
- Documentation of measurement fixture characterization and of optional correction methods such as fixture de-embedding, phase correction, re-normalization etc.
- Results for S-parameter
  - Result as dB value with related limit
  - Diagram with logarithmic frequency axis up to minimum  $f = 1\,000\text{ MHz}$
- Results for TDR- Measurements
  - Result as differential impedance (Ohms) with related limit
  - Measurement results are to be presented in one diagram in the following format:
    - Linear scale for X- axis in time
    - Linear scale for additional X- axis in length (m, calculated using  $2/3$  of  $c_0$  or real phase velocity of cable / connector and correction of two-way of pulse propagation)

### 8.1.1.4 Measurement fixtures

Measurement fixtures shall provide a sufficient electrical and mechanical quality, so that the measurement result is not dominated by the characteristics of the measurement fixture.

The used measurement fixtures need to have low insertion loss, high symmetry within the two lines of a differential pair and very good matching to  $50\ \Omega$  single ended impedance.

The electrical limits in Subsections 4.3.1.4.1 to 4.3.1.4.3 shall be met. The measurement fixtures or instructions for proper design should be provided by the connector or cable manufacturer. Examples of appropriate measurement fixtures are given in OPEN Alliance TC9, Channel and Components Requirements for 1000BASE-T1 Link Segment Type A (UTP and STP class 1).

Measurement fixtures shall provide a low resistance, low inductance connection from fixture ground to the surface of the conductive table or conductive drum, e.g. by using conductive plates or stands. This reference ground connection shall be direct, reaching up 10 mm to the connection point of the DUT.

Phase stability of VNA test cables and test fixtures is essential to ensure sufficient accuracy of mode conversion measurements. The phase reference plane may optionally be moved to the DUT by VNA features such as “port extension”. The detailed description of such techniques is not scope of this document and the correct application shall be demonstrated and documented. The open fixture balance requirements in [Table 11](#) shall still be met before and after applying the phase correction features

mentioned above. Serial numbers shall be assigned to the measurement fixtures to allow individual identification.

Test fixtures based on printed circuit boards as shown in [Figure 4](#) are recommended for connector and channel tests. PCB based test fixtures are also recommended for connecting receptacle terminals in cable assembly measurements. Pin terminals of cable assemblies, i.e. inline connector terminals, can be connected with MDI test heads as described in Chapter 5. Examples of appropriate PCB based measurement fixtures are given in Annex [A.1](#), [Figure A.1-1](#) and [Figure A.1-2](#). Open Alliance TC9 Channel and Components Requirements for 1000BASE-T1 Link Segment Type A (UTP and / or STP class 1).

[Figure 4](#) shows the PCB based measurement fixture example

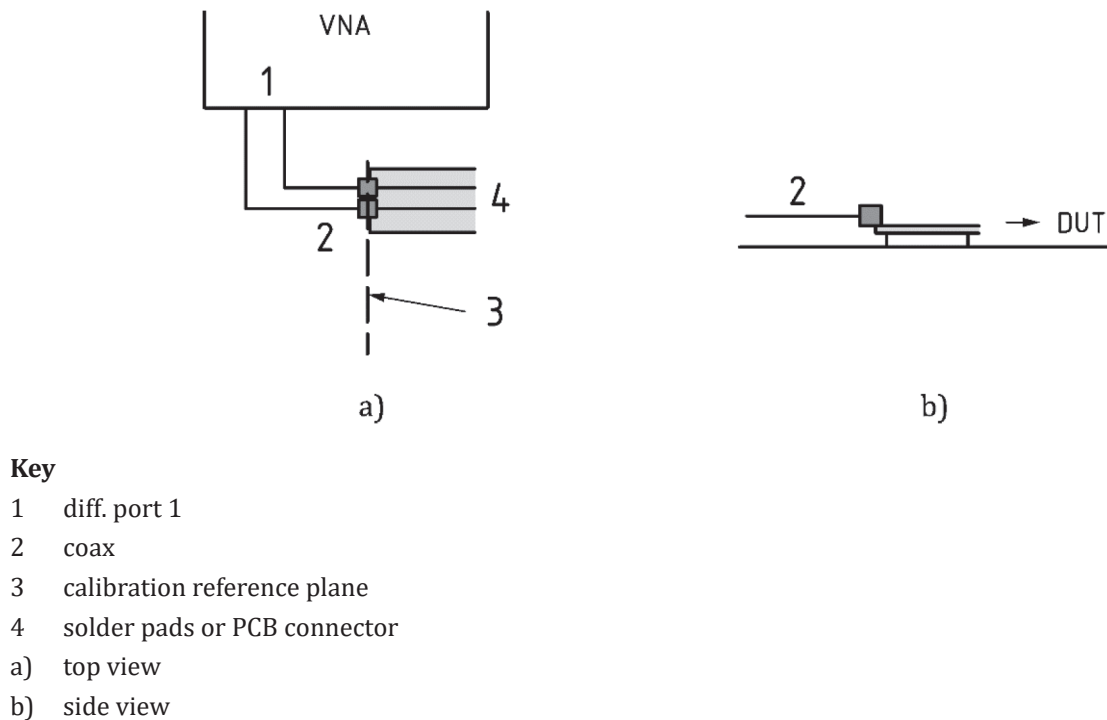
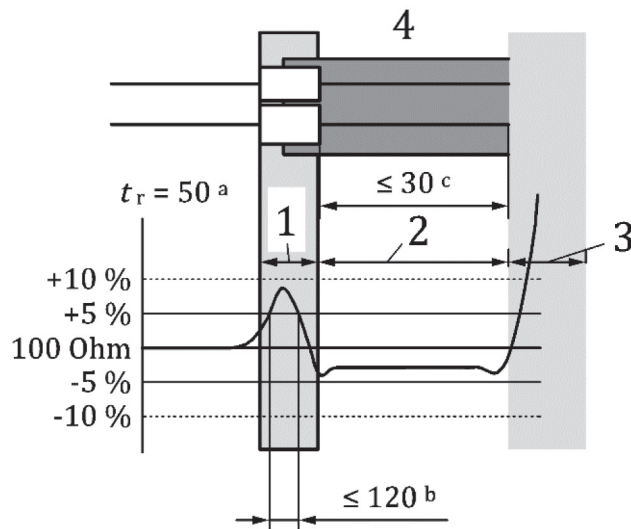


**Figure 4 — PCB based measurement fixture example**

#### 8.1.1.4.1 Impedances and termination

The characteristic impedance differential mode is  $100\ \Omega$  and is matched in some test configurations by dual  $50\ \Omega$  load terminations. The impedance of the test fixture shall be within  $(100\ \Omega \pm 5)\%$  at a rise time of 50 ps. An impedance tolerance of  $\pm 10\%$  is permitted if the 5 % limit is exceeded no longer than 120 ps round trip time or 60 ps propagation time (see [Figure 5](#)). The PCB connector including its footprint shall be excluded from the measurement fixture impedance requirement.

[Figure 5](#) shows the characteristic impedance of test fixtures



### Key

- 1 coax
- 2 microstrip or strip-line
- 3 open fixture end
- 4 test fixture
- <sup>a</sup> Filter (ps).
- <sup>b</sup> Round trip (ps) ( $\leq 60$  ps propagation time).
- <sup>c</sup> Length (mm).

**Figure 5 — Characteristic impedance of test fixtures**

The maximum trace length on PCB based test fixtures shall not exceed 30 mm to ensure sufficient fixture return loss. Longer trace lengths are permitted in case of design constraints, e.g. for larger size multi-port connectors if the following requirements are met to avoid inaccurate return loss results:

- Impedance tolerance of the traces smaller than  $\pm 5\%$

or

- Removing the fixture by de-embedding techniques or by shifting the calibration plane to the DUT leads; the detailed description of such techniques is not in the scope of this document. The correct application of these methods needs to be demonstrated and documented. The open fixture balance requirements in [Table 11](#) shall still be met after applying the correction methods mentioned above.

When a measurement fixture is used as termination and is not connected to the measurement VNA, it shall provide  $50\ \Omega$  single ended termination to common ground for each line of the differential pair, resulting in a common mode termination of  $25\ \Omega$ .

#### 8.1.1.4.2 Balance

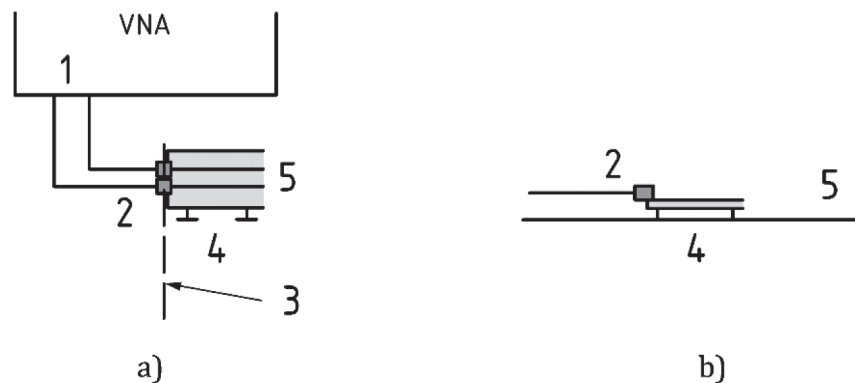
Unbalance within measurement fixtures can be caused by length differences within the differential pairs or capacitive or inductive unbalance. The type of PCB material with its structure and orientation of the glass weave have a major impact, as well as the thickness of the traces.

The mode conversion properties of the measurement fixture can be measured against the open port in a differential one port measurement to obtain LCL ( $S_{dc11}$ ).

After calibrating to the reference plane at the coaxial end of the measurement cables, connect to the measurement fixture and measure mode conversion against the open end of the fixture as shown in

**Figure 6.** If the measurement fixture contains a PCB connector to be tested, the characterization of the measurement fixture shall take place without the connector soldered to it. For board connectors that require a specific design of PCB footprint, then an alternative characterization method may be specified by the connector supplier.

**Figure 6** shows the validation of measurement fixture balance



#### Key

- 1 diff. port 1
- 2 coax
- 3 calibration reference plane
- 4 GND
- 5 open PCB fixture i.e. without PCB connector soldered
- a) top view
- b) side view

**Figure 6 — Validation of measurement fixture balance**

The mode conversion parameter LCL ( $S_{dc11}$ ) of the measurement fixture shall comply with the requirements given in [Table 11](#) for UTP and [Table 12](#) for STP connectors.

**Table 11 — Measurement fixture balance requirements for UTP**

| Test Parameter |            | Requirement                                                                                                                                                                                                            |
|----------------|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| LCL            | $S_{dc11}$ | $\geq \begin{cases} 61 & 10 \leq f \leq 80 \\ 83 - 11,51 \log_{10}(f) & 80 < f \leq 600 \end{cases} dB$ $10 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 200 $\Omega$ (CM) |

*This limits may be exempted for 100BASE-T1*

**Table 12 — Measurement fixture balance requirements for STP class 1**

| Test Parameter |            | Requirement                                                                                                                                           |
|----------------|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| LCL            | $S_{dc11}$ | $\geq \begin{cases} 56 & 10 \leq f \leq 50 \\ 81,2 - 14,83 \log_{10}(f) & 50 < f \leq 600 \end{cases} dB$ $10 \leq f \leq 600$ , frequency $f$ in MHz |

*This limits may be exempted for 100BASE-T1*

**Figure 7a** and **7b** shows the LCL requirements for fixture balance UTP and STP class 1

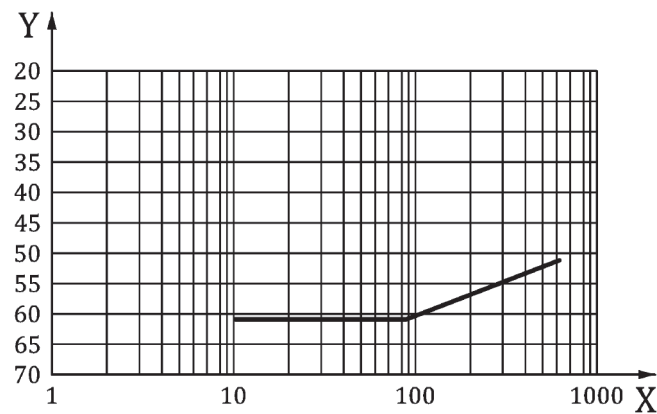
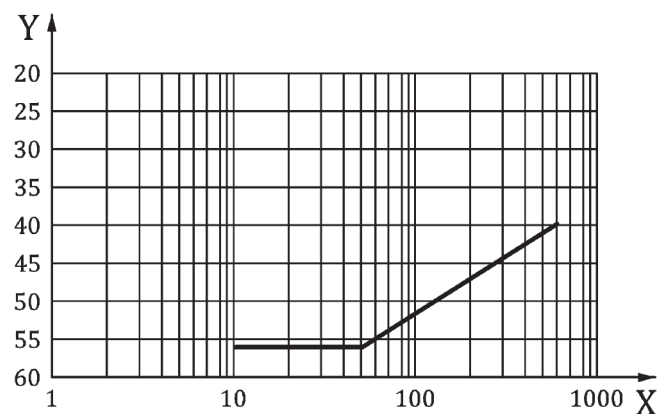


Figure 7a — LCL requirements for fixture balance UTP



**Key**  
X frequency (MHz)  
Y mode conversion loss (dB)

Figure 7b — LCL requirements for fixture balance STP class 1

8.1.1.4.3 Crosstalk

The internal crosstalk within test fixtures for multi-port connectors shall be lower than the limit to measure against. The near end crosstalk of the test fixture needs to be measured without the PCB connector soldered to it. The transmission from each port shall be measured to any other neighbouring port. For board connectors that require a specific design of PCB footprint, then an alternative characterization method may be specified by the connector supplier. Identical trace length for all pairs on the fixture PCB is recommended.

[Figure 8](#) shows the validation of multi-port measurement fixture crosstalk

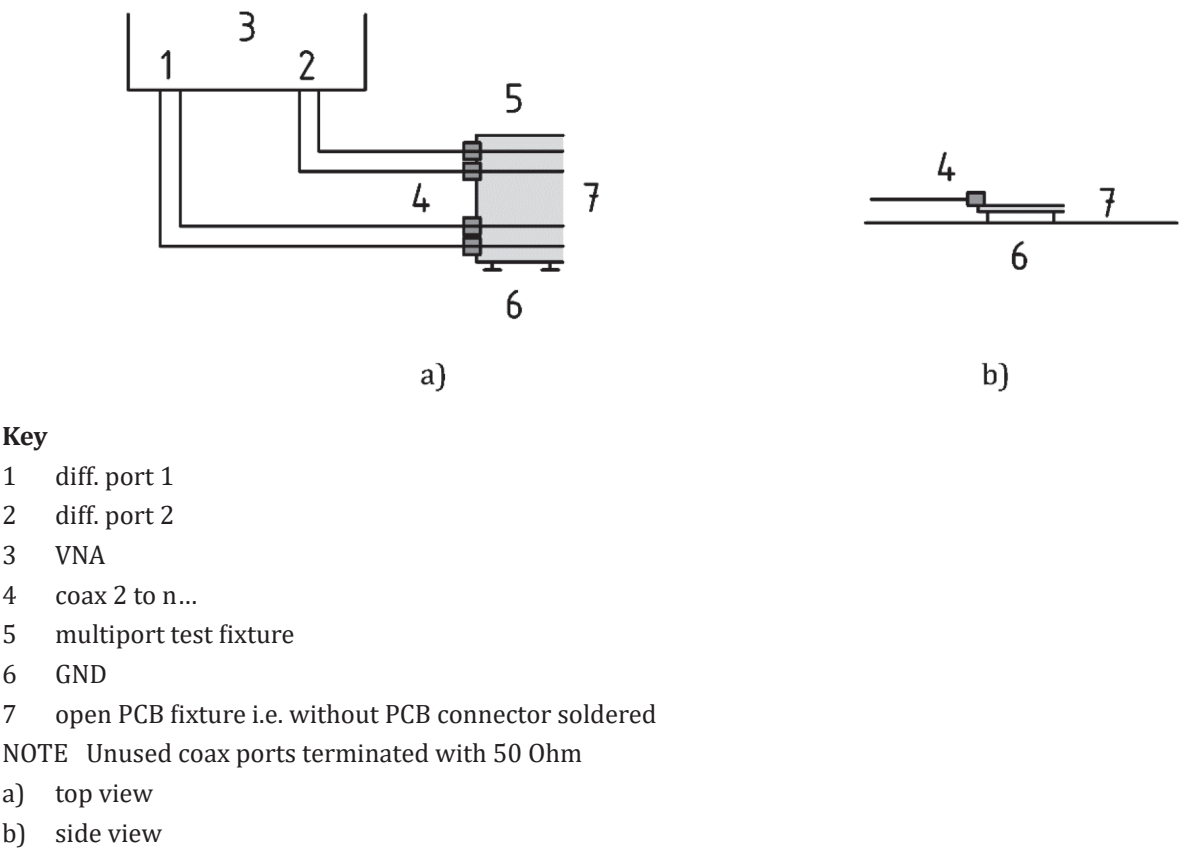


Figure 8 — Validation of multi-port measurement fixture crosstalk

The validation of measurement fixtures crosstalk needs to be carried out exemplarily on an appropriate number of samples per measurement fixture type and not for the specific instance that is used in a multi-port connector test, assuming that the electrical variations on PSANEXT caused by manufacturing tolerances of the measurement fixture are low enough. This aims at allowing the connector manufacturer to provide multi-port connectors that are pre-mounted to a measurement fixture instead of the need to solder them after the measurement fixture characterization. The crosstalk within multi-port measurement fixtures shall comply with the requirements given in [Table 13](#).

Table 13 — Measurement fixture crosstalk requirements

| Test Parameter     |                                                | Requirement                                                                                                                                                                                                                                                                                                                         |
|--------------------|------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PSANEXT            | $S_{dd31}, S_{ddy x}$                          | $\geq \begin{cases} 63 - 10 \log_{10} \left( \frac{f}{100} \right) & 1 \leq f \leq 100 \\ 63 - 15 \log_{10} \left( \frac{f}{100} \right) - 6 \left( \frac{f - 100}{400} \right) & 100 < f \leq 600 \end{cases} dB$<br>$1 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 200 $\Omega$ (CM) |
| ANEXTDC<br>ANEXTDS | $S_{dc31}, S_{dcy x}$<br>$S_{ds31}, S_{dsy x}$ | $\geq \begin{cases} 61 & 10 \leq f \leq 80 \\ 83 - 11,51 \log_{10} (f) & 80 < f \leq 600 \end{cases} dB$<br>$10 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 200 $\Omega$ (CM)                                                                                                          |

*This limits may be exempted for 100BASE-T1*

[Figure 9](#) shows the PSANEXT requirement for fixture crosstalk

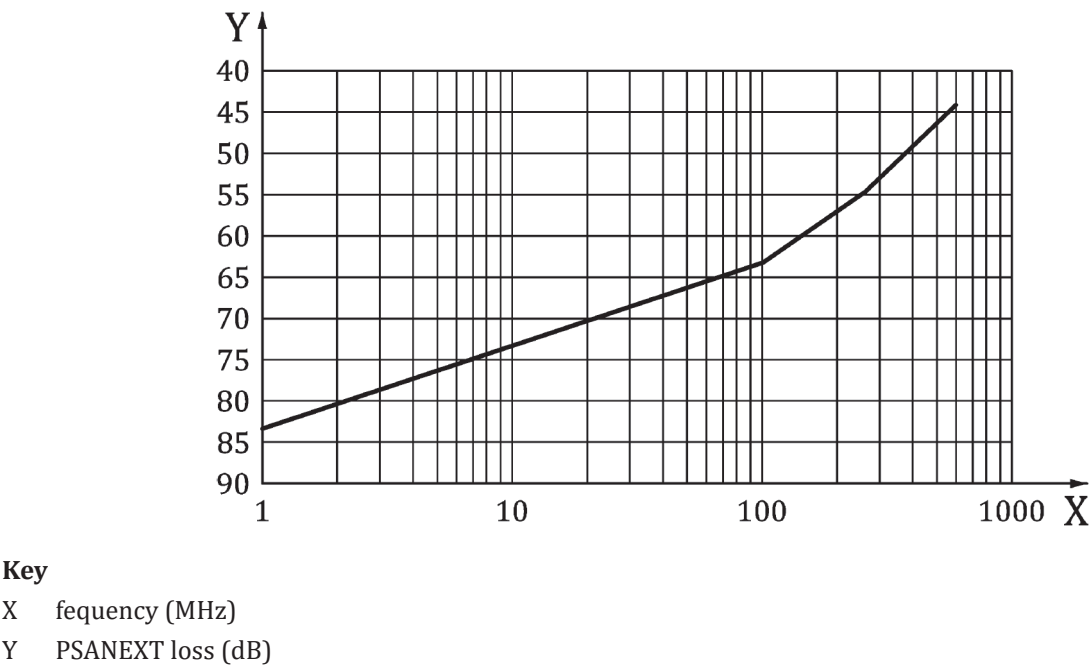


Figure 9 — PSANEXT requirement for fixture crosstalk

Figure 10 shows the ANEXTDC and ANEXTDS requirement for fixture cross mode conversion (UTP)

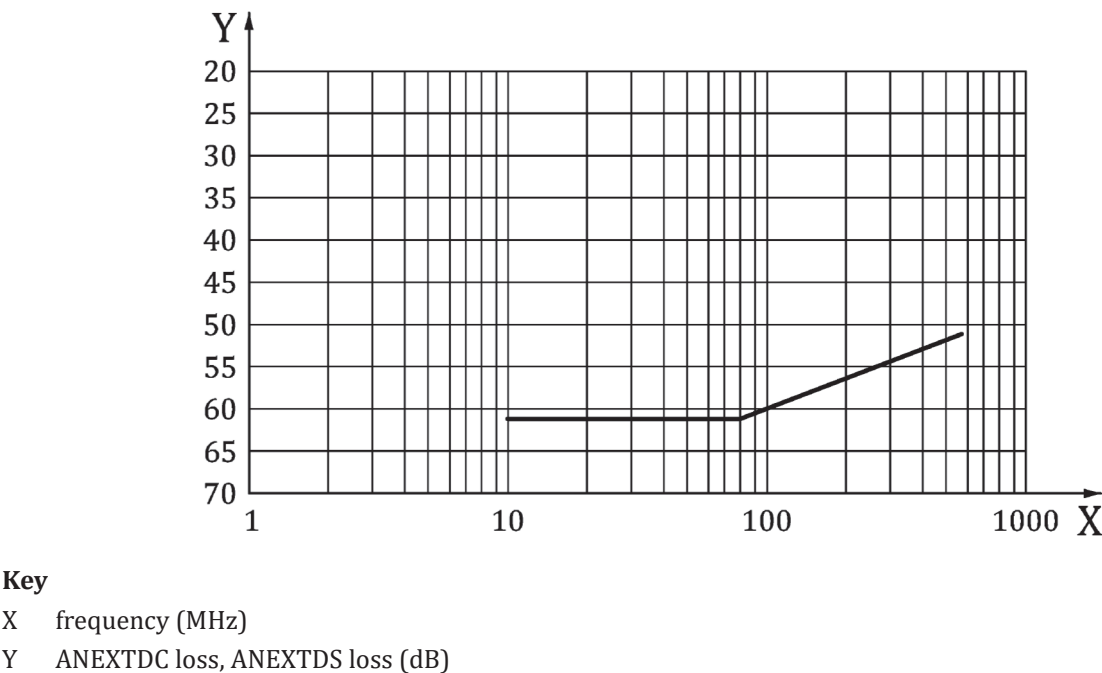


Figure 10 — ANEXTDC and ANEXTDS requirement for fixture cross mode conversion (UTP)

8.1.2 Measurement setups for connectors – UTP connectors

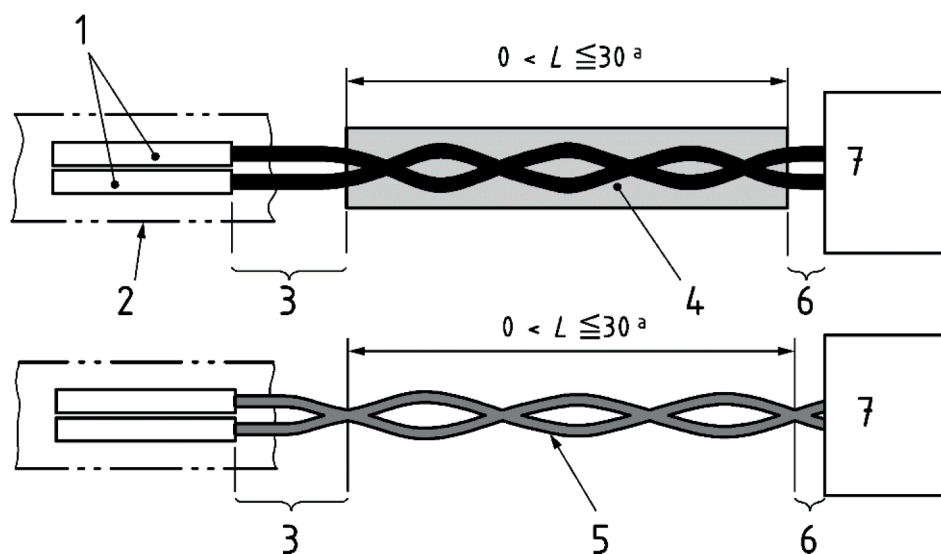
8.1.2.1 Setups for SCC parameters

Connectors are measured including a short piece of cable on each cable connector. This allows capturing the properties of the whole connector including the area of wire transition from contacts to the cable.

The transition area therefore is part of the measurement result and shall be assembled as used in the application. The cable shall meet the requirements from [ISO 19642-12](#) and should have a characteristic impedance as close as possible to the system impedance. The length shall be no longer than 30 mm to keep the influence of the cable on the measurement result relatively low. For inline connectors, the length of the cable should be identical on both sides. The cable length is measured along that cable section where the cable geometry remains unchanged compared to the original cable construction, i.e. the length of the remaining cable jacket. In case of unjacketed cables, the distance between the first and the last crossing location of the twisted wires shall be measured (see [Figure 11](#)). A multiple of half of the cable twist length from the contact area to the measurement fixture will provide the same orientation of the conductors and ease handling. Omitting the cable, i.e. cable length zero, is not permitted.

The transition length between cable and test fixture shall be as short as possible depending on the actual fixture design. The transition length between cable and connector shall comply the specifications of the component manufacturers.

[Figure 11](#) shows the maximum cable length for connector measurements



#### Key

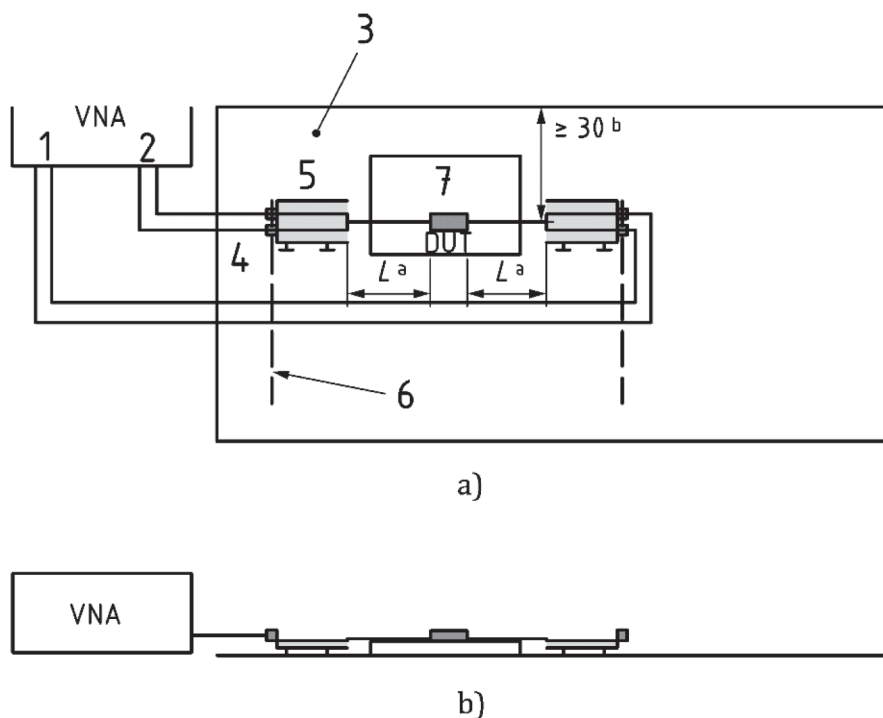
- 1 connector contacts
- 2 connector housing
- 3 transition to connector
- 4 cable with jacket
- 5 cable without jacket
- 6 transition to fixture
- 7 test fixture
- <sup>a</sup> Length (mm).

**Figure 11 — Maximum cable length for connector measurements**

Connectors should be measured with PCB based fixtures as shown in [Figure 4](#) on both sides of the DUT. The board connectors are mounted directly on the fixture PCB as specified for the individual component by the manufacturer. The free cable leads of the cable side connector are attached to the PCB traces by soldering or by other appropriate methods. The fixture balance requirements should still be met when the cable leads are attached. The cable ends and the contacts within the DUT shall be placed in 10 mm height over a contiguous conducting ground plane. This distance may be increased as necessary in case of mechanical constraints, e.g. due to large connector housings. A dielectric insulation material ( $\epsilon_r < 1,4$ ) between the connector and the ground plane may be used for mechanical support. The dimensions of the ground plane need to be large enough to support the DUT including 30 mm

distance to the ground perimeter (3 x height above the ground plane). [Figure 12](#) and [Figure 13](#) show test setups to measure SCC S-parameters of mated inline connectors and mated PCB connectors:

[Figure 12](#) shows the inline connector VNA measurement setup

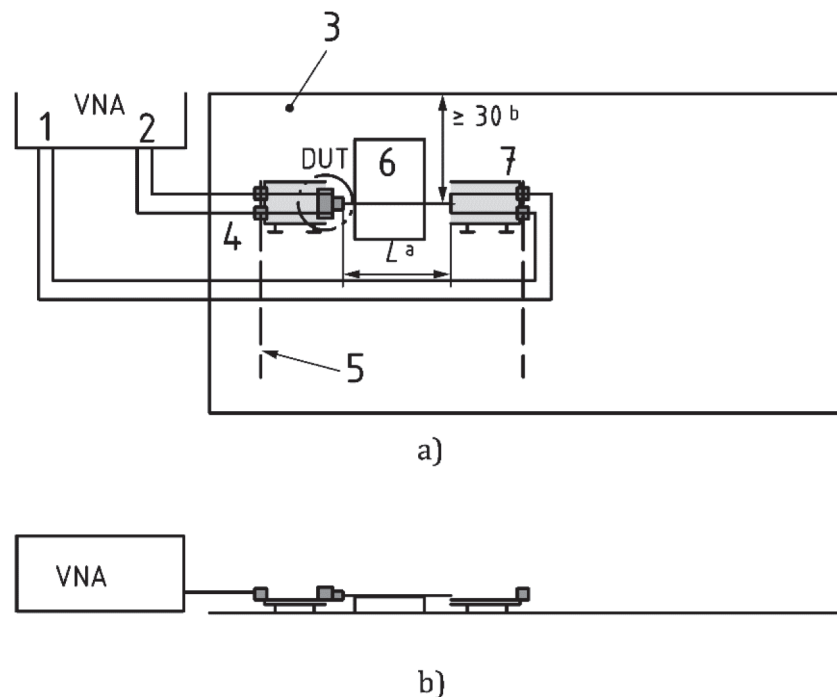


#### Key

- 1 diff. port 1
- 2 diff. port 2
- 3 ground plane
- 4 coax
- 5 test fixtures
- 6 calibration reference plane
- 7 insulation 10 mm
- a) top view
- b) side view
- <sup>a</sup>  $L \leq 30$  (mm).
- <sup>b</sup> (mm).

**Figure 12 — Inline connector VNA measurement setup**

[Figure 13](#) shows the PCB connector VNA measurement setup

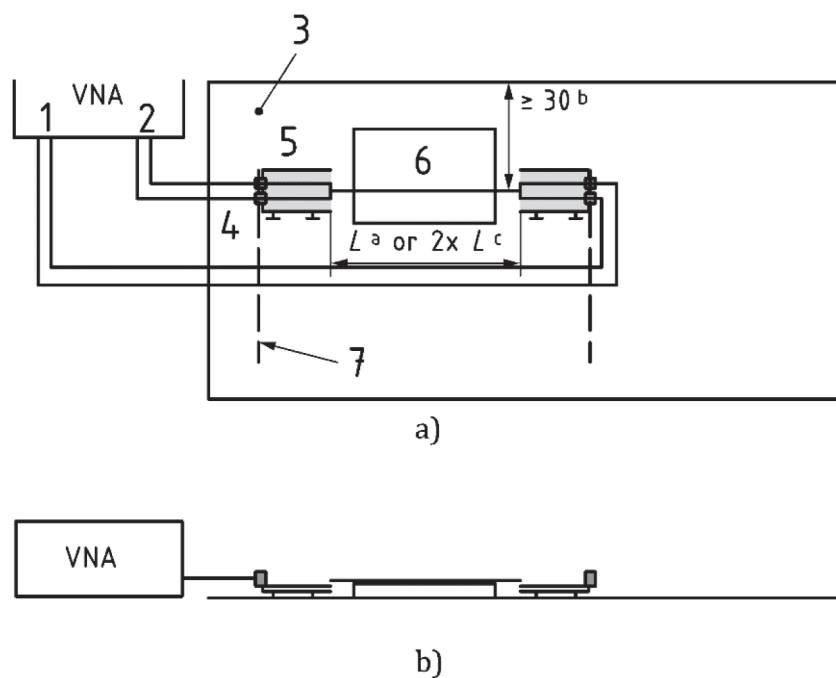
**Key**

- 1 diff. port 1
- 2 diff. port 2
- 3 ground plane
- 4 coax
- 5 calibration reference plane
- 6 insulation 10 mm
- 7 test fixtures
- a) top view
- b) side view
- <sup>a</sup>  $L \leq 30$  (mm).
- <sup>b</sup> (mm).

**Figure 13 — PCB Connector VNA measurement setup**

The insertion loss and propagation delay of test fixtures and cable leads may be subtracted from the transmission measurement result of the PCB or inline connector. Therefore, the DUT is replaced by a direct through cable connection as shown in [Figure 14](#). The same cable type shall be used with a length of  $1 \times L$  for PCB connectors and  $2 \times L$  for inline connectors, where  $L$  is identical to the length used in the connector measurement. This compensation method is only applicable for measuring the insertion loss and propagation delay parameter.

[Figure 14](#) shows the thru connection to measure insertion loss and propagation delay of fixtures and cable leads

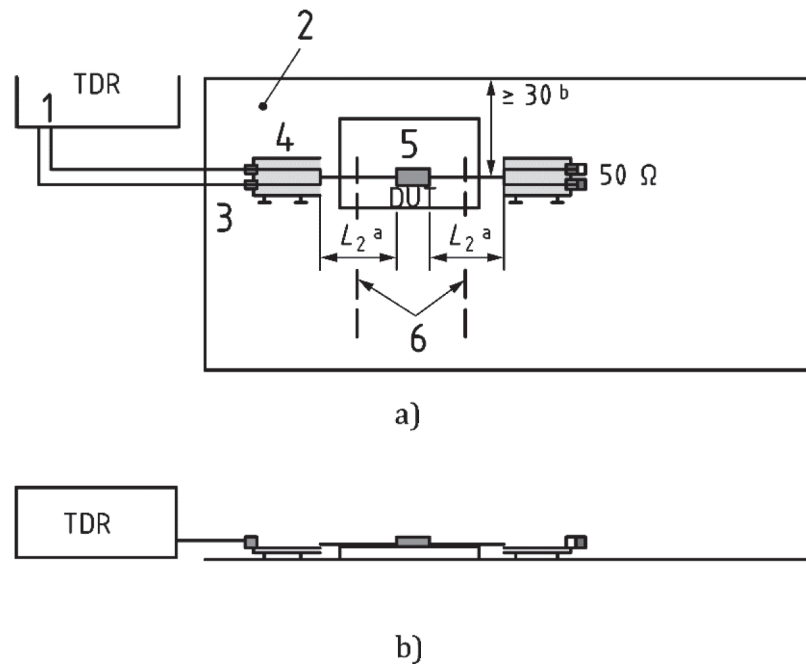
**Key**

- 1 diff. port 1
- 2 diff. port 2
- 3 ground plane
- 4 coax
- 5 test fixtures
- 6 isolation 10 mm
- 7 calibration reference plane
- a) top view
- b) side view
- a  $L \leq 30$  (mm) for PCB connectors.
- b (mm).
- c  $2 \times L$  for inline connectors.

**Figure 14 — Thru connection to measure insertion loss and propagation delay of fixtures and cable leads**

CIDM measurements are carried out in a one port differential setup. The same setup as used for VNA measurements may be used, but with the termination of the measurement fixture with  $50 \Omega$  loads on the far end side, see [Figure 15](#). The rise time for the measurements is 500 ps and may be applied by software filtering within the TDR scope.

[Figure 15](#) shows the inline connector CIDM measurement setup

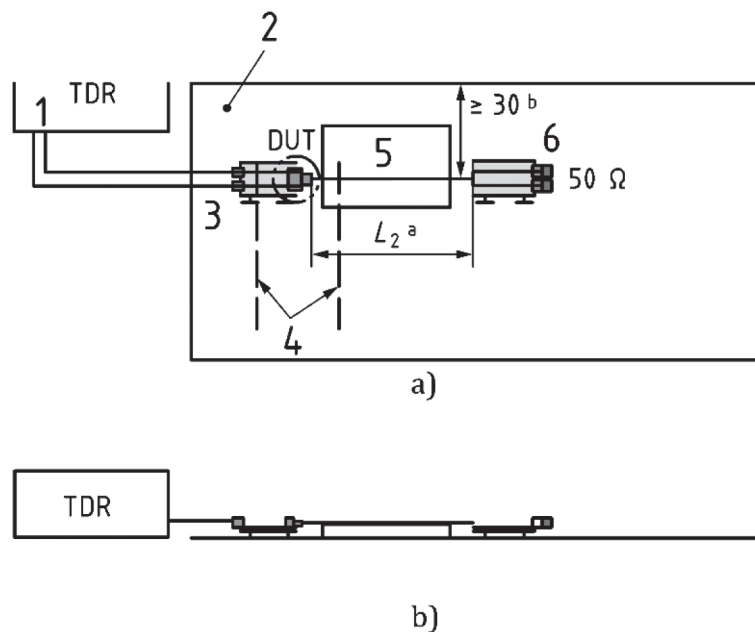
**Key**

- 1 diff. port 1
- 2 ground plane
- 3 coax
- 4 test fixtures
- 5 isolation 10 mm
- 6 evaluation window
- a) top view
- b) side view
- <sup>a</sup>  $L_2 = 250 \text{ mm to } 260 \text{ mm}$ .
- <sup>b</sup> (mm).

**Figure 15 — Inline connector CIDM measurement setup**

CIDM of PCB connectors is measured in combination with its corresponding cable connector counterpart in a 250 mm to 260 mm cable assembly. The far end side of the cable is terminated at the test fixture. The electrical length on the test fixture between the coaxial ports and the DUT needs to be sufficiently long to separate the DUT from the coaxial connectors at 500 ps rise time, see [Figure 16](#).

[Figure 16](#) shows the PCB connector CIDM measurement setup



#### Key

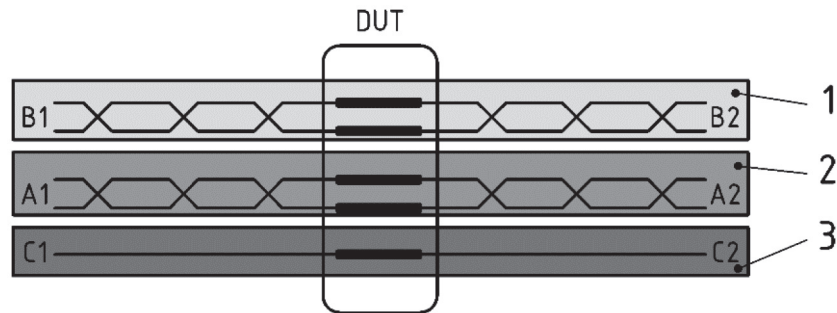
- 1 diff. port 1
- 2 ground plane
- 3 coax
- 4 evaluation window
- 5 isolation 10 mm
- 6 test fixtures
- a) top view
- b) side view
- <sup>a</sup>  $L_2 = 250 \text{ mm to } 260 \text{ mm}$ .
- <sup>b</sup> (mm).

**Figure 16 — PCB connector CIDM measurement setup**

#### 8.1.2.2 Setups for ES parameters

Additional parameter in the environmental system are crosstalk and cross conversion in multi-port connectors. Such connectors consist of one or more Ethernet differential pairs and potentially additional other contacts. These additional contacts can be used as general purpose signal line, power supply or differential signals other than Ethernet. (see [Figure 17](#)).

[Figure 17](#) shows the multi-port inline connector



#### Key

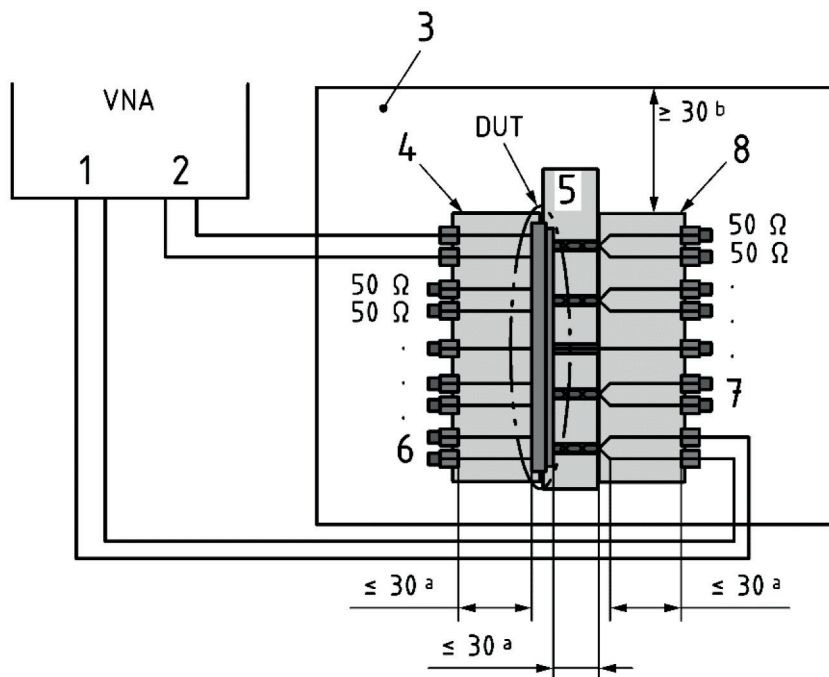
- 1 differential pair (non ethernet)
- 2 1000BASE-T1 ethernet pair
- 3 signal line / power line

**Figure 17 — Multi-port inline connector**

The individual pairs of multi-port connectors shall be tested as like single-ports connectors according to the measurement setup described in Chapter 4.3.2.1. Suitable PCB based multi-port test fixtures shall be used for the multi-port board connectors on both DUT sides. The test fixtures shall fulfil the balance requirements described in Chapter 4.3.1.4.2 and the impedance requirements including trace length given in Chapter 4.3.1.4.1. The crosstalk requirements in Section 4.3.1.4.3 shall be met in addition. The multi-port board connectors are mounted directly on the multi-port fixture PCB as specified for the individual component by the manufacturer. The free cable leads of the cable side connector are attached to the traces of the multi-port fixture board by soldering or by other appropriate methods. The fixture balance requirements should still be met when the cable leads are attached. The requirements to the short cable pieces on the cable side of a multi-port connector are the same as specified in Section 4.3.2.1. for single-port connectors. The DUT shall be placed at a height of 10 mm above conductive ground in the same way as specified for single-port connectors in Section 4.3.2.1. Unused fixture ports shall be terminated during the individual measurements.

[Figure 18](#) shows the differential port 1 of the VNA connected to the far end port, in order to measure AFEXT, AFEXTDC and AFEXTDS of the multi-port PCB connector. Unused differential or single ended ports are terminated with 50  $\Omega$  loads.

[Figure 18](#) shows the multi-port PCB connector measurement setup for AFEXT, AFEXTDC and AFEXTDS



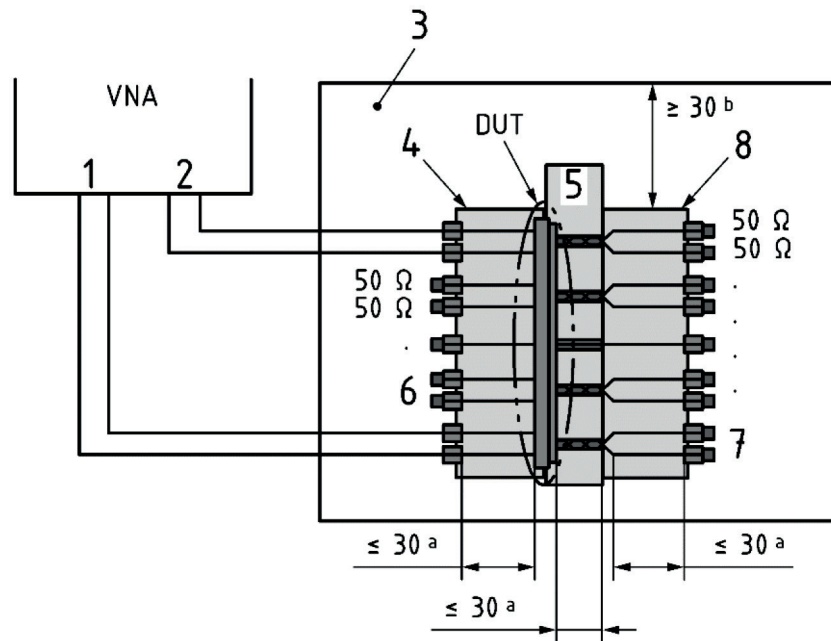
#### Key

- 1 diff. port 1
- 2 diff. port 2
- 3 ground plane
- 4 multiport test fixture 2 to n ports
- 5 isolation 10 mm
- 6 unused ports terminated
- 7 unused ports terminated
- 8 multiport test fixture 2 to n ports
- a (mm).
- b (mm).

**Figure 18 — Multi-port PCB connector measurement setup for AFEXT, AFEXTDC and AFEXTDS**

[Figure 19](#) shows port 1 connected to the near end measurement fixture to measure ANEXT of the multi-port PCB connector.

[Figure 19](#) shows the multi-port PCB connector measurement setup for ANEXT



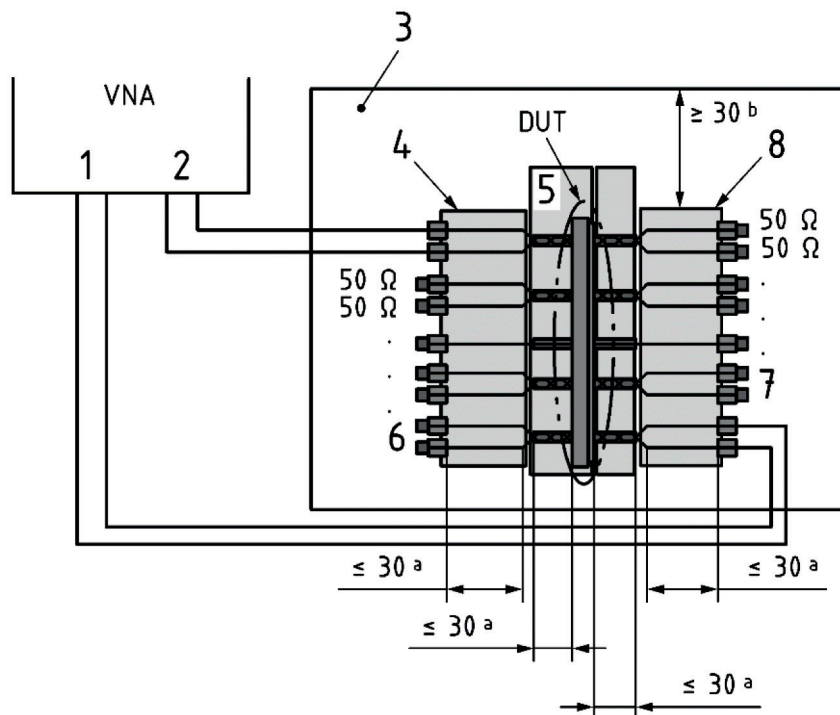
#### Key

- 1 diff. port 1
- 2 diff. port 2
- 3 ground plane
- 4 multiport test fixture 2 to n ports
- 5 isolation 10 mm
- 6 unused ports terminated
- 7 unused ports terminated
- 8 multiport test fixture 2 to n ports
- a (mm).
- b (mm).

**Figure 19 — Multi-port PCB connector measurement setup for ANEXT**

[Figure 20](#) shows the differential port 1 of the VNA connected to the far end port, in order to measure AFEXT, AFEXTDC and AFEXTDS of the multi-port inline connector.

[Figure 20](#) shows the multi-port inline connector measurement setup for AFEXT, AFEXTDC and AFEXTDS



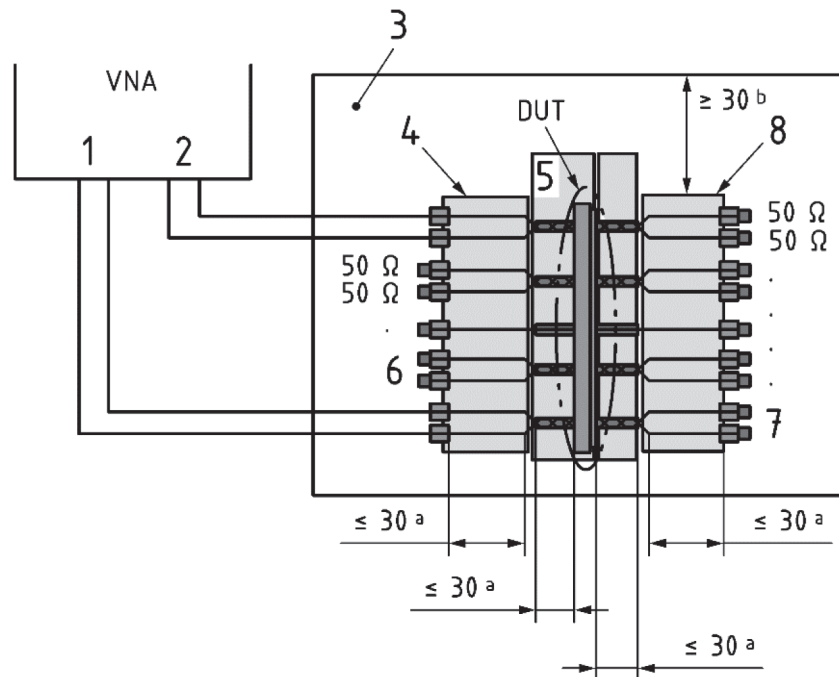
# Key

- 1 diff. port 1
- 2 diff. port 2
- 3 ground plane
- 4 multiport test fixture 2 to n ports
- 5 isolation 10 mm
- 6 unused ports terminated
- 7 unused ports terminated
- 8 multiport test fixture 2 to n ports
- a (mm).
- b (mm).

**Figure 20 — Multi-port inline connector measurement setup for AFEXT, AFEXTDC and AFEXTDS**

[Figure 21](#) shows port 1 connected to the near end measurement fixture in order to measure ANEXT of the multi-port inline connector.

[Figure 21](#) shows the multi-port inline connector measurement setup for ANEXT



#### Key

- 1 diff. port 1
- 2 diff. port 2
- 3 ground plane
- 4 multiport test fixture 2 to n ports
- 5 isolation 10 mm
- 6 unused ports terminated
- 7 unused ports terminated
- 8 multiport test fixture 2 to n ports
- a (mm).
- b (mm).

**Figure 21 — Multi-port inline connector measurement setup for ANEXT**

The measurement shall be repeated for every pair of the multi-port measurement fixture. To calculate the power-sum crosstalk (PSANEXT and PSANEXT) for each port, the measurement results for all ports need to be summed. Equations how to calculate the power-sum crosstalk from individual transmission measurements are given in Chapter 4.4. Each port to be used with 1000BASE-T1 shall comply with the specified alien-crosstalk limits in Section 4.3.2.3.

#### 8.1.2.3 Requirements for connectors (UTP)

This section specifies the connector requirements in context of the standalone communication channel without the coupling parameters to neighbour wires.

Table 14 — Requirements for connectors UTP (SCC + ES)

| Test Parameter                                                 |                                                | Requirement                                                                                                                                                                                                                                                                                                                            |
|----------------------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Requirements for Standalone Communication Channel (SCC)</b> |                                                |                                                                                                                                                                                                                                                                                                                                        |
| CIDM                                                           | $Z_{RF}$                                       | $(100 \Omega \pm 5) \%$ (at 500 ps rise time)                                                                                                                                                                                                                                                                                          |
| Propagation Delay                                              | $t_d$                                          | $\leq 667$ ps<br>$2 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 25 $\Omega$ (CM)                                                                                                                                                                                                          |
| IL                                                             | $S_{dd21}$                                     | $\leq (0,01 \sqrt{f})$ dB<br>$1 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 25 $\Omega$ (CM)                                                                                                                                                                                              |
| RL                                                             | $S_{dd11}, S_{dd22}$                           | $\geq \begin{pmatrix} 38 & 1 \leq f < 75 \\ 20 - 20 \log_{10} \left( \frac{f}{600} \right) & 75 \leq f \leq 600 \end{pmatrix} dB$<br>$1 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 25 $\Omega$ (CM)                                                                                      |
| LCL<br>LCTL                                                    | $S_{dc11}, S_{dc22}$<br>$S_{dc21}, S_{dc12}$   | $\geq \begin{pmatrix} 55 & 10 \leq f \leq 80 \\ 77 - 11,51 \log_{10}(f) & 80 < f \leq 600 \end{pmatrix} dB$<br>$10 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 25 $\Omega$ (CM)                                                                                                           |
| <b>Requirements for Environment System (ES)</b>                |                                                |                                                                                                                                                                                                                                                                                                                                        |
| PSANEXT                                                        | $S_{dd31}, S_{ddy x}$                          | $\geq \begin{pmatrix} 57 - 10 \log_{10} \left( \frac{f}{100} \right) & 1 \leq f \leq 100 \\ 57 - 15 \log_{10} \left( \frac{f}{100} \right) - 6 \left( \frac{f - 100}{400} \right) & 100 < f \leq 600 \end{pmatrix} dB$<br>$1 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 25 $\Omega$ (CM) |
| PSAFEXT                                                        | $S_{dd41}, S_{ddy x}$                          | $\geq \left( 46,67 - 20 \log_{10} \left( \frac{f}{100} \right) \right) dB$<br>$1 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 25 $\Omega$ (CM)                                                                                                                                             |
| AFEXTDC<br>AFEXTDS                                             | $S_{dc41}, S_{dcy x}$<br>$S_{ds45}, S_{dsy x}$ | $\geq \begin{pmatrix} 50 & 10 \leq f \leq 80 \\ 72 - 11,51 \log_{10}(f) & 80 < f \leq 600 \end{pmatrix} dB$<br>$10 \leq f \leq 600$ , frequency $f$ in MHz<br>Port reference impedances: 100 $\Omega$ (DM), 25 $\Omega$ (CM)                                                                                                           |

Lower limits in ISO 21111-8 may be applicable for 100BASE-T1

Figure 22 shows the insertion loss limit for connectors

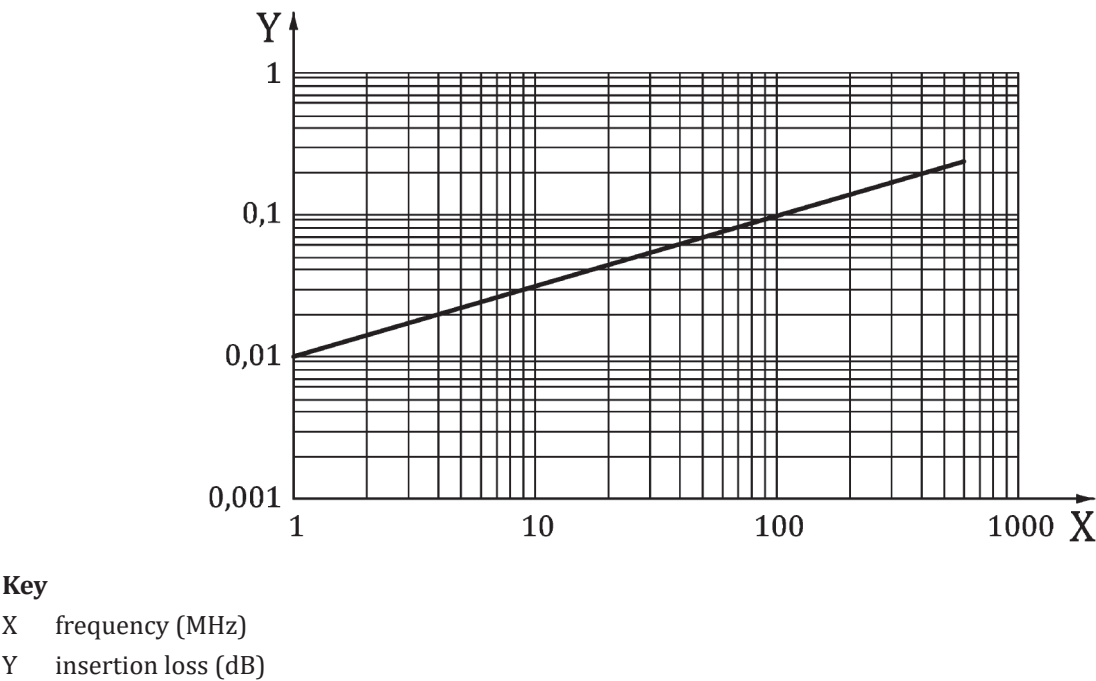


Figure 22 — insertion loss limit for connectors

Figure 23 shows the return loss limit for connectors

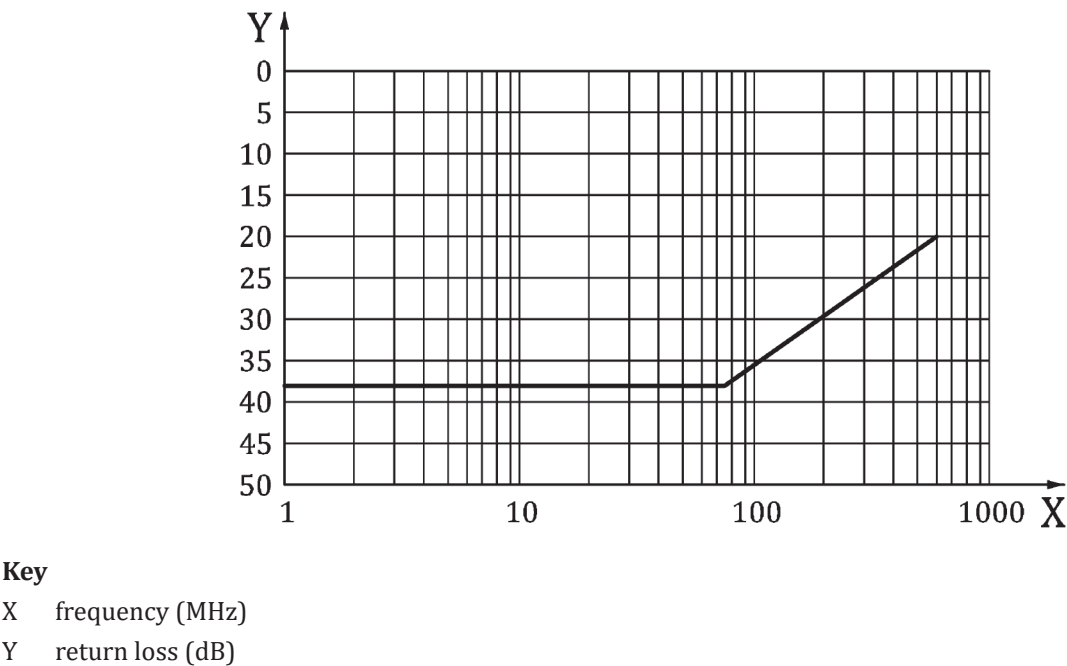


Figure 23 — Return loss limit for connectors

Figure 24 shows the LCL / LCTL limit for connectors

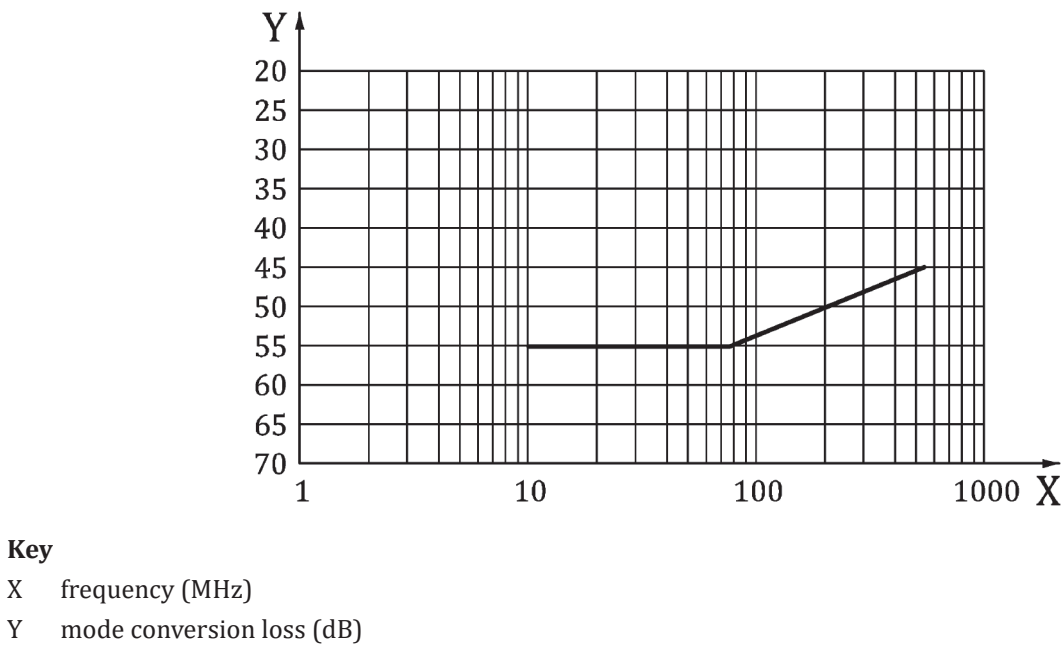


Figure 24 — LCL / LCTL limit for connectors

Figure 25 shows the PSANEXT loss limit for connectors

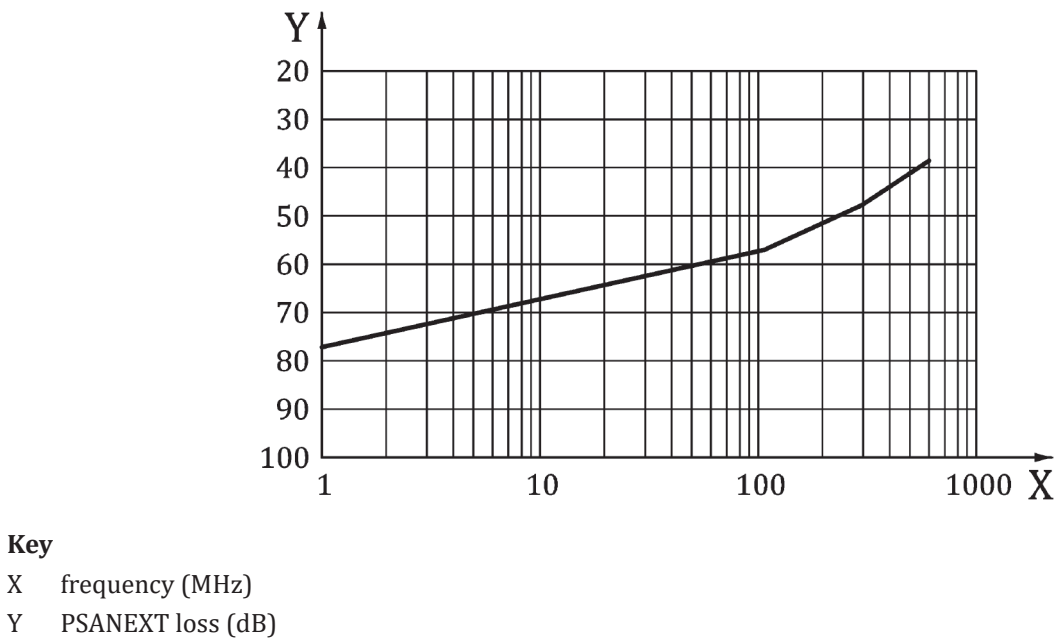


Figure 25 — PSANEXT loss limit for connectors

Figure 26 shows the PSAFEXT loss limit for connectors