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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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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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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

ISO/DIS 8092-6

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*

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This document is circulated as received from the committee secretariat.

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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).

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This document was prepared by Technical Committee [or Project Committee] ISO/TC [or ISO/PC] , , Subcommittee SC .

This edition cancels and replaces the edition (ISO :), which has been technically revised.

The main changes compared to the previous edition are as follows:

A list of all parts in the ISO 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.

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 (e.g. E-mobility, autonomous driving, camera, radar, body control, driver assistance, multimedia, active safety).

Building the complete system requires a supply of various components from different equipment suppliers. It is important for vehicle manufacturers 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 as well as harness inline connections.

Due to the location of the device in the vehicle, the connector design could be angled or straight.

In general, the Ethernet requirements are specified in ISO/IEC/IEEE8802-3:2021. The ISO21111series 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, in the ISO 21111-8.

This document defines terms and definitions, general performance requirements of a multi-port connection and the interface definition of a single-port, waterproof 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 document also applies to connectors designed to be disconnected after mounting in the vehicle for repair and maintenance purposes.

This document 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.

Table 1 indicates the suggested specification purpose. Table 2 summarizes interfaces in Annexes A.

Table 1 — Overview of applicable and referenced ISO standards and specifications

<i>Standards</i>		<i>UTP</i>		<i>STP class 1 (semi shielded connector)</i>	<i>STP class 2 (fully shielded connector)</i>
<i>IEEE802.3</i>		100BASE-T1	1000BASE-T1	1000BASE-T1	1000BASE-T1
<i>Open Alliance</i>		[1] TC2 / [2] TC9	[2] TC9	[3] TC9	[3] TC9
<i>ISO</i>	Channel	ISO 21111-8			
	Connector	ISO 8092-6 (ISO 21111-8)	ISO 8092-6	ISO 8092-6	ISO 8092-6
	Cable	ISO 19642-12	ISO 19642-12		
Further Explanation on ISO 21111-8: We should try to harmonize test matrices, setups, methods etc...and use the OPEN Alliance 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 2 — Overview of the interfaces shown in the appendix

	100BASE-T1	1000BASE-T1	unsealed	waterproof
Type A	X*	X	X	X
Type B	X*	X	X	X
Type C	X*	X	X	X
Type D	X*	X	X	
Type E	X		X	
Type F	X*	X	X	X
Type G	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 requirements are defined in this document. Definition of the interface is described as informative, which is limited to the representation of the single-port connection.

This document defines terms and definitions, general performance requirements of a multi-port connection and the interface definition of a single-port, waterproof 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 document also applies to connectors designed to be disconnected after mounting in the vehicle for repair and maintenance purposes.

This document is not applicable to internal connections of electronic devices.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO8092-2 and the following apply.

ISO and IEC maintain terminology 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

non-conducting feature for inserting the terminal and providing insulation between terminals.

3.1.2 cable attachment

any permanent junction of cable to terminal.

3.1.3 connector

assembly of terminal, *housing* (3.1.1) and related parts that terminate a cable for the purpose of providing connection and disconnection to a suitable mating appliance.

3.1.4 connector coding

mechanical feature to provide differentiation, preventing mating of *connectors* (3.1.3) not intended to be mated.

3.1.5 single-port

one Ethernet-port composed of 2 ways (pins or terminals).

3.1.6 multi-port

more than one Ethernet-port arranged inside one *housing*(3.1.1).

3.1.7 coaxial cable

two-pole cables with a concentric cross-section as described like in ISO 19642-1.

3.2 Terms related to RF systems and properties

3.2.1 100BASE-T1 Ethernet

standardized in IEEE 802.3, the physical layer that 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 802.3, the physical layer that 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.

NOTE 1000BASE-T1 Ethernet has been standardized in ISO/IEC/IEEE 8802-3.

4 Abbreviated terms

AACRF	alien attenuation to crosstalk ratio far-end
α_c	coupling attenuation
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
α_s	screening attenuation
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
CM	common mode

c_0	speed of light in vacuum
DM	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 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-Parameters	scattering parameter
STP	shielded twisted pair
TDR	time domain reflectometry
UTP	unshielded twisted pair cable
VNA	vector network analyser

5 Test and requirements

5.1 General

5.1.1 Preconditioning for environment classes

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

5.1.2 Test conditions

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

A cable in compliance with the ISO19642-12 and -13 series is recommended. The cable or cables used shall be noted in the test report.

The cable attachment shall be performed in accordance with the terminal manufacturer's specifications, or as agreed between the 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 ± 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.

6 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 ISO/IEC/IEEE8802-3:2021, Clause 97 and in References [2] and [3].

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

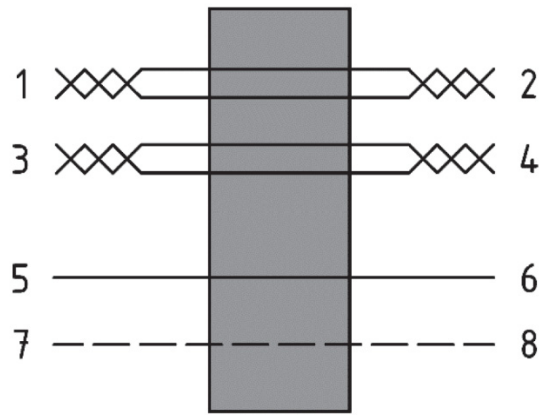
The amount of additional EMC margin, i.e. the degree of shielding and coupling attenuation, can depend on the specific implementation in the vehicle. Two electromagnetic environment classes are defined to provide the most flexibility for choosing suitable components. STP class 1 relies on lower mode 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 the subject of this document.

7 General electrical definitions and requirements

7.1 General

All definitions for the communication channel, cables and connectors are valid for any temperature within the range that is required by the application. Measurements are generally carried out at room temperature unless specified differently in 5.1.

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



- 1 port 1 (differential)
- 2 port 2 (differential)
- 3 port 3 (differential)
- 4 port 4 (differential)
- 5 port 5 (single ended)
- 6 port 6 (single ended)
- 7 port 7 (single ended)
- 8 port 8 (single ended)

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

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

Table 3 — Definitions for RF and S-parameter

Test parameter	Symbol or related S- parameter	Description
Impedance		
CIDM	Z_{RF}	Characteristic impedance differential mode (TDR measurement)
Single channel characteristics (e.g. port 1,2)		
Propagationdelay	t_d	Propagation delay i.e. phase delay according to EN 50289-1-7, see formula (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
Cross talk and cross conversion to neighbour channels and / or signal lines		
ANEXT	$S_{dd31}, S_{ddy x}$	Alien near end cross talk loss
AFEXT	$S_{dd41}, S_{ddy x}$	Alien far end cross talk loss
PSANEXT	see formula 1	Power sum alien near end cross talk loss

Table 3 (continued)

PSAFEXT	see formula 2	Power sum alien far end cross talk loss
PSAACRF	see formula 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

Single channel characteristics (e.g. port 1,2)

a_c	see formula 6	Coupling attenuation
a_s	see formula 7	Screening attenuation

The following formulae 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 Formula (1):

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

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 Formula (2):

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

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 Formula (3):

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

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 Formula (4):

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

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 Formula (5) as described in EN 50289-1-7.

$$t_d = -Phase(S_{dd21}) / (360 \times f) \quad (5)$$

where

f is expressed in Hz;

t_d in s;

phase angle in degree.

The coupling attenuation a_c of the device under test is calculated by Formula (6) as follows as described in IEC62153-4-7 and IEC62153-4-9.

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

where

a_c : is the coupling attenuation related to the normalized radiating impedance of 150 Ω 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 Ω 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 Formula (7) as described in IEC62153-4-7 and IEC62153-4-9. 3-port measurement setup using VNA without balun shall be used with the differential feeding port set to excite in common mode.

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

where

a_s : is the screening attenuation related to the normalized radiating impedance of 150 Ω 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 Ω . 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 Formula (8):

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

where

β : is the bandwidth in GHz;

t_{rise} : is the rise time (10 – 90) % in ns;

k : is the factor. The values for the factor are shown in Table 7;

7.2 General setup and measurement fixtures

7.2.1 Required measurements fixtures

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 parameters stated in Table 4 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 Ω single ended
		Frequency range	UTP: $f = 300$ kHz to 1000 MHz STP: $f = 1$ MHz to 2000 MHz
Characteristic impedance (CIDM)	TDR test system	Type	2 channel differential mode
		Port reference impedance	50 Ω single ended / 100 Ω differential mode
		Rise time	Pulse generator: ≤ 25 ps internal (≤ 50 ps at measurement fixture). Rise time needs to be adjustable to the required values (50ps / 500ps). All values 10 % to 90 %
Coupling attenuation and screening attenuation	VNA	Type	3- port vector network analyzer
		Port reference impedance	50 Ω single ended
		Frequency range	$f = 1$ MHz to 1000 MHz
	Test tube apparatus	Metallic non ferromagnetic triaxial test tube arrangement according to IEC 62153-4-7 with lengths as specified in 7.2.6.3 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 Tables 8 and 9.

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 10 and shall be documented in the test report.

7.2.2 Vector network analyzer (VNA) settings

To assure a high degree of reliability for transmission measurements, the following precautions are required (as specified in EN 61935-1).

- 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 7.2.4.
- Accurate and consistent resistor loads shall be used for each pair throughout the test sequence.
- The cable shall be placed to satisfy the requirements for the single tests and needs to be fixed throughout the test sequence.
- 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 7.2.4 during the complete test sequences including handling operation for connecting and disconnecting the DUTs.

- e) Test cables, i.e. coaxial cables between measurement devices and measurement fixtures, shall be chosen in a way that the calibration requirements in Table 8 and 9 are fulfilled.
- f) Overload conditions of the network analyzer shall be avoided.
- g) The VNA shall provide enough stability and low drift to ensure to meet the accuracy requirements in Tables 8 and 9 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)
Sweep f_{Start}	300 kHz	1 MHz
Sweep f_{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	≤ 500 Hz	≤ 500 Hz
Port reference impedance differential mode ^b	100 Ω	100 Ω
Port reference impedance common mode ^b	25 Ω for connector measurements and MDI test head 200 Ω for all other measurements	25 Ω
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 ^a	Single time measurement ^a
Smoothing function	Deactivated	Deactivated
^a Multiple averaging setting may be used with recording the actual averaging time used. ^b The single ended 4-port S-parameters are captured with 50 Ω port reference impedances. This results in 100 Ω differential mode and 25 Ω 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 Table 5 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 gives an example.

Table 6 — Recommended VNA settings for de-embedding

Parameter	Value
Sweep f_{Start}	1 MHz
Sweep f_{Stop}	≥ 2 GHz
Sweep type	Linear
Sweep points	$\geq 2\ 000$
^a Multiple averaging setting may be used with recording the actual averaging time used. ^b The window function type has relation to the recommended stop frequency in table 7. This stop frequency needs to be adjusted if an alternative window function is used.	

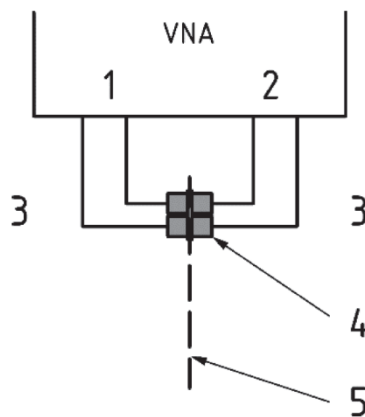
Table 6 (continued)

Output power	Minimum -10 dBm
Measurement bandwidth	≤ 3 kHz
Port reference impedance differential mode	100 Ω
Port reference impedance common mode	25 Ω
Data calibration kit (VNA)	Use an appropriate calibration kit. (The calibration kit shall be identified in the test report.)
Averaging function	Single time measurement ^a
Smoothing function	Deactivated
Filtering for TDR functions	Hann window or similar window ^b
^a Multiple averaging setting may be used with recording the actual averaging time used. ^b The window function type has relation to the recommended stop frequency in table 7. This stop frequency needs to be adjusted if an alternative window function is used.	

Table 7 — Bandwidth^a settings for different windows to achieve a rise time^b of 500 ps

Window function	Factor (<i>k</i>)	Bandwidth (β) for 500 ps
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
^a The bandwidth is the stop frequency of the sweep which is used for the measurement. ^b 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.



- 1 differential port 1
- 2 differential port 2
- 3 coaxial cable
- 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 8 for the UTP 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 UTP class

Test parameter		Requirement
RL	S_{dd11}, S_{dd22}	$\geq \begin{pmatrix} 44 & 1 \leq f < 75 \\ 26 - 20\log\left(\frac{f}{600}\right) & 75 \leq f \leq 600 \end{pmatrix} dB$ (1) $1 \leq f \leq 600$, frequency f is expressed in MHz Port reference impedances: 100 Ω (DM), 200 Ω (CM)
LCL LCTL	S_{dc11}, S_{dc22} S_{dc21}, S_{dc12}	$\geq \begin{pmatrix} 61 & 10 \leq f \leq 80 \\ 83 - 11.51\log(f) & 80 < f \leq 600 \end{pmatrix} dB$ (2) $10 \leq f \leq 600$, frequency f is expressed in MHz Port reference impedances: 100 Ω (DM), 200 Ω (CM)

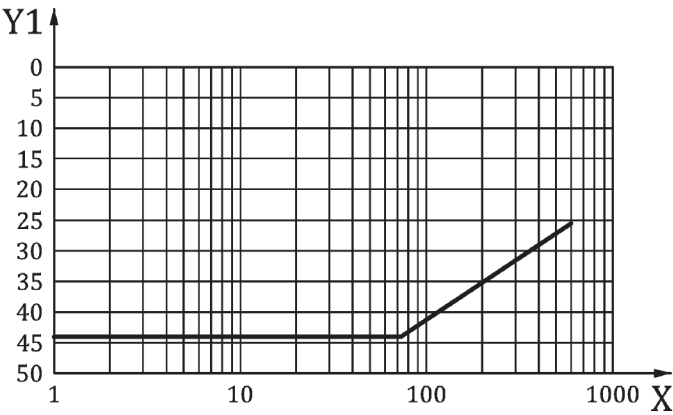
These limits may be exempted for 100BASE-T1.

The LCL, LCTL and RL parameters shall comply with the requirements given in Table 9 for the STP channel and components. The LCL calibration accuracy may also be verified with measurement cables in open condition at the calibration plane.

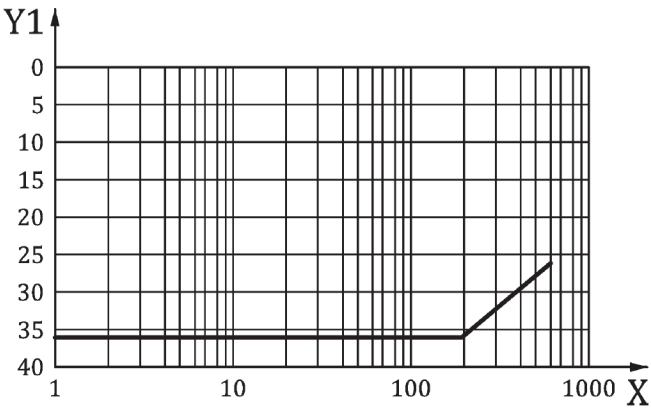
Table 9 — VNA calibration accuracy requirements for STP class 1

Test parameter		Requirement
RL	S_{dd11}, S_{dd22}	$\geq \begin{pmatrix} 36 & 1 \leq f < 190 \\ 26 - 20\log\left(\frac{f}{600}\right) & 190 \leq f \leq 600 \end{pmatrix} dB$ (3) $1 \leq f \leq 600$, frequency f is expressed in MHz
LCL LCTL	S_{dc11}, S_{dc22} S_{dc21}, S_{dc12}	$\geq \begin{pmatrix} 56 & 10 \leq f \leq 50 \\ 81.2 - 14.83\log(f) & 50 < f \leq 600 \end{pmatrix} dB$ (4) $10 \leq f \leq 600$, frequency f is expressed in MHz

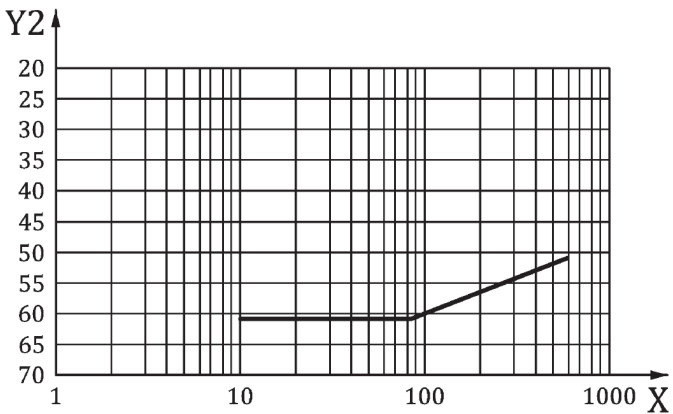
Figures a) and b) show the return loss requirement for VNA calibration accuracy UTP and STP class 1.
Figures c) and d) show the LCL/LCTL loss requirement for VNA calibration accuracy UTP and STP class 1.



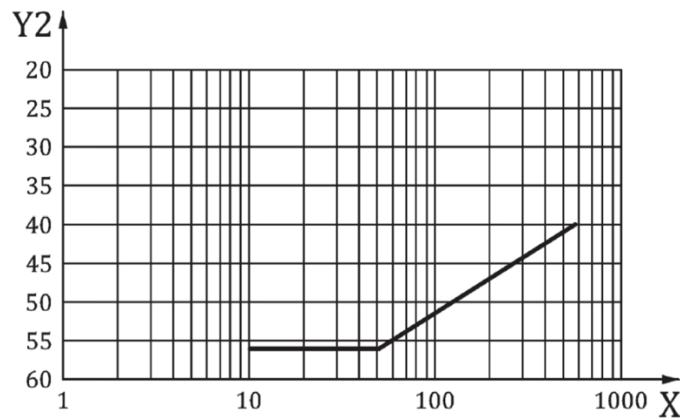
3 a) — a) Return loss requirement for VNA calibration accuracy UTP



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



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



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

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

Figure 3 — Return loss requirement and 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 10).

Table 10 — Recommended VNA settings for impedance measurements

Parameter	Value
Sweep f_{Start}	1 MHz, (10 MHz) ^c
Sweep f_{Stop}	2 GHz, (20 GHz) ^c
Sweep type	Linear
Sweep points	2 000
Filtering	Hann window or similar window ^b
TDR type	Step
Output power	Minimum -10 dBm
Measurement bandwidth	≤ 500 Hz for UTP (≤ 3 kHz for STP class 1 or 2)
Port reference impedances	50 Ω single ended port impedances (This results in 100 Ω 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 ^a
Smoothing function	Deactivated

^a Multiple averaging setting may be used with recording the actual averaging time used.

^b The window function type has relation to the recommended stop frequency table 7. This stop frequency needs to be adjusted if an alternative window function is used.

^c Values in brackets are suitable for characterization of test fixtures (see 4.3.1.4.1 7.2.4?) and MDI test heads (see 5.2 8.2?).

To achieve high degree of comparability of test results, the VNA settings given in Table 11 are recommended for coupling attenuation measurements. The used VNA setting for each parameter of Table 11 shall be documented in the test report.

Table 11 — Recommended VNA settings for coupling and screening attenuation measurements

Parameter	Value
Sweep f_{Start}	1 MHz
Sweep f_{Stop}	1 GHz
Sweep type	Linear
Sweep points	1 000
Output power	Minimum -10 dBm
Measurement bandwidth	≤ 1 kHz
Port reference impedance differential mode	100 Ω
Port reference impedance common mode	25 Ω
Data calibration kit (VNA)	Use an appropriate calibration kit. (The calibration kit shall be identified in the test report.)
Averaging function	Single time measurement ^a
Smoothing function	Deactivated
^a A multiple averaging setting may be used with recording the actual averaging time used.	

7.2.3 Presentation of measurement results

Test results shall be documented in the following way:

- a) documentation of test conditions (e.g. humidity, temperature, cable length);
- b) documentation of cable types and production number (also for S-parameter and coupling _attenuation measurements of connectors);
- c) documentation of used calibration kit and of calibration accuracy in thru-thru configuration;
- d) pictures of test set-up and measurement fixture;
- e) documentation of measurement fixture characterization and of optional correction methods such as fixture de-embedding, phase correction, re-normalization, etc.;
- f) results for S-parameter:
 - 1) result as dB value with related limit;
 - 2) diagram with logarithmic frequency axis up to minimum $f = 1\,000$ MHz;
- g) results for TDR- measurements:
 - 1) result as differential impedance (Ω) with related limit;
 - 2) measurement results are to be presented in one diagram in the following format:
 - 1) linear scale for X- axis in time;
 - 2) 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).

7.2.4 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.