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TECHNICAL REPORT

Information technology – Generic cabling for customer premises – Part 9905: Guidelines for the use of installed cabling to support 25GBASE-T application

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FOREWORD

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ISO/IEC TR 11801-9905, which is a Technical Report, was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

The list of all currently available parts of the ISO/IEC 11801 series, under the general title *Information technology — Generic cabling for customer premises*, can be found on the IEC website.

This Technical Report has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This Technical Report is to be read in conjunction with ISO/IEC/IEEE 8802.3:2017/AMD3.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

INTRODUCTION

This document provides guidance to determine whether and which installed channels will support 25GBASE-T. It takes into account the design goals for 25GBASE-T equipment such as:

a) the frequency signal range up to 1 250 MHz;

b) the support of two-connector channels up to 30 m in length.

The requirements of 25GBASE-T are fully defined in ISO/IEC/IEEE 8802-3:2017/AMD3.

Installed two-connector channels which are characterized up to 1 250 MHz and support all the requirements of the ISO/IEC/IEEE 8802-3:2017/AMD3 link segment are expected to support the 25GBASE-T application.

Characterization of channels using Category 7_A components is described in 4.4.

Characterization of channels using Category 7 components is described in 4.5.

Characterization of channels using Category 6_A components is described in 4.6.

This document also provides mitigation procedures to improve the performance of installed channels to the point where the 25GBASE-T application is supported. Additionally, this document recommends the use of Class I and Class II channels to support 25GBASE-T in new installations.

Class I and Class II channels according to ISO/IEC 11801-1 will support 25GBASE-T without mitigation.

Component requirements are not provided in this document and should not be inferred from the channel limits provided.

INFORMATION TECHNOLOGY – GENERIC CABLING FOR CUSTOMER PREMISES –

Part 9905: Guidelines for the use of installed cabling to support 25GBASE-T application

1 Scope

This part of ISO/IEC 11801, which is a Technical Report,

a) provides guidance on how to select and assess installed channels which conform to ISO/IEC 11801-1, and clarify if they also support ISO/IEC/IEEE 8802-3:2017/AMD3 for 25GBASE-T;

b) specifies the methods to assess whether installed channels constructed with Category 7_A, 7, or 6_A components meet the 25GBASE-T requirements;

c) provides guidance to identify which channels are likely to meet the 25GBASE-T requirements to avoid unnecessary testing;

d) provides mitigation techniques to improve the performance of installed channels to meet the 25GBASE-T requirements;

e) provides cabling recommendations for new installations.

NOTE 1 The channel transmission performance specified in this document is derived from the 25GBASE-T requirements in ISO/IEC/IEEE 8802-3:2017/AMD3.

NOTE 2 This document does not re-specify component or channel definitions of ISO/IEC 11801-1.

2 Normative references

The following referenced documents are indispensable for the application 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/IEC 11801-1, *Information technology – Generic cabling systems – Part 1: General requirements*

ISO/IEC/IEEE 8802-3:2017/AMD3, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet – Amendment 3: Physical layers and management parameters for 25 Gb/s and 40 Gb/s operation, types 25GBASE-T and 40GBASE-T*

3 Terms, definitions and abbreviations

For the purposes of this document, the terms, definitions and abbreviations given in ISO/IEC 11801-1 apply.

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

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

4 Cabling channel specifications for 25 GBASE-T

4.1 General

This document provides guidelines for the assessment of installed cabling channels for the additional requirements of ISO/IEC/IEEE 8802-3:2017/AMD3 for 25GBASE-T. It is assumed that each installed channel does fulfil the requirements of its appropriate cabling class defined in ISO/IEC 11801-1.

The requirements defined in Clause 4 are a combination of the original class requirements of the installed cabling and the requirements in support of 25GBASE-T.

For a balanced cabling installation covered by this document:

a) the channel performance is specified according to ISO/IEC 11801-1 and additionally according to Clause 4 (or appropriate subclause);

b) the interfaces to the cabling are specified according to ISO/IEC 11801-1:2017, Clause 10, with respect to mating interfaces;

c) local regulations concerning safety and EMC apply.

The test procedures for balanced cabling installations are specified in IEC 61935-1 in accordance with ISO/IEC 11801-1 and ISO/IEC 14763-2.

4.2 25GBASE-T application specifications

NOTE 1 These specifications are consistent with the link segment specifications of ISO/IEC/IEEE 8802-3:2017/AMD3.

NOTE 2 All specifications are based on a channel length of 30 m with 2 connections.

4.2.1 Return loss

The return loss (RL) of each pair of a channel is specified in Table 1. The limits shown in Table 2 are derived from the formulae at key frequencies.

The return loss requirement is specified for both ends of the cabling. Return loss (RL) values at frequencies where the insertion loss (IL) is below 3,0 dB are for information only.

Table 1 – Return loss for a channel

Class	**Frequency** MHz	**Minimum return loss** dB
I	$1 \leq f < 10$	19,0
	$10 \leq f < 40$	$24 - 5\lg(f)$
	$40 \leq f < 130$	16,0
	$130 \leq f < 1\,000$	$35 - 9\lg(f)$
	$1\,000 \leq f \leq 1\,250$	8,0

Table 2 –Return loss values for a channel at key frequencies

Frequency MHz	Minimum return loss dB
	Class
	I
1	19,0
16	18,0
100	16,0
250	13,4
500	10,7
600	10,0
1 000	8,0
1 250	8,0

4.2.2 Insertion loss/attenuation

The insertion loss (IL) of each pair of a channel is specified in Table 3. The limits shown in Table 4 are derived from the formulae at key frequencies.

Table 3 – Insertion loss for a channel

Class	Frequency MHz	Maximum insertion loss [a] dB
I	$1 < f \leq 500$	$\left(0{,}634\sqrt{f}+0{,}00156\times f+\frac{0{,}078}{\sqrt{f}}\right)$ [b]
	$500 < f \leq 1\,250$	$\left(0{,}60698\sqrt{f}+0{,}00277\times f+\frac{0{,}078}{\sqrt{f}}\right)$ [c]

[a] Insertion loss (IL) at frequencies that correspond to calculated values of less than 4,0 dB revert to a maximum requirement of 4,0 dB.

[b] This formula is derived using: $0{,}312\times\left(1{,}8\sqrt{f}+0{,}005\times f+\frac{0{,}25}{\sqrt{f}}\right)+2\times\left(0{,}02\times\sqrt{f}\right)+0{,}032\,4\times\sqrt{f}$

[c] This formula is derived using:

$$0{,}312\times\left(1{,}8\sqrt{f}+0{,}005\times f+\frac{0{,}25}{\sqrt{f}}\right)+2\times\left(0{,}006\,49\times\sqrt{f}+0{,}000\,605\times f\right)+0{,}032\,4\times\sqrt{f}$$

Table 4 – Insertion loss values for a channel at key frequencies

Frequency MHz	Maximum insertion loss dB Class I
1	4,0
16	4,0
100	6,5
250	10,4
500	15,0
600	16,5
1 000	22,0
1 250	24,9

4.2.3 NEXT

4.2.3.1 Pair-to-pair NEXT

The NEXT between each pair combination of a channel is specified in Table 5. The limits shown in Table 6 are derived from the formulae at key frequencies.

The NEXT requirement is specified for both ends of the cabling. NEXT values at frequencies where the insertion loss (IL) is below 4,0 dB are for information only.

Table 5 – NEXT for a channel

Class	Frequency MHz	Minimum NEXT [a] dB
I	$1 \leq f \leq 500$	$-20\lg\left(10^{\frac{75,3-15\lg(f)}{-20}} + 2\times 10^{\frac{94-20\lg(f)}{-20}}\right)$
	$500 < f \leq 1\,250$	$-20\lg\left(10^{\frac{75,3-15\lg(f)}{-20}} + 2\times 10^{\frac{40-38\lg(f/500)}{-20}}\right)$

[a] NEXT at frequencies that correspond to calculated values of greater than 65,0 dB revert to a minimum requirement of 65,0 dB.

Table 6 – NEXT values for a channel at key frequencies

Frequency MHz	**Minimum channel NEXT** dB
	Class
	I
0,1	–
1	65,0
16	53,9
100	40,5
250	33,6
500	28,4
600	26,2
1 000	19,6
1 250	16,5

4.2.3.2 Power sum NEXT (PS NEXT)

The PS NEXT of each pair of a channel is specified in Table 7. The limits shown in Table 8 are derived from the formulae at key frequencies.

Table 7 – PS NEXT for a channel

Class	**Frequency** MHz	**Minimum PS NEXT** [a] dB
I	$1 \le f \le 500$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}} + 2\times 10^{\frac{91-20\lg(f)}{-20}}\right)$
	$500 < f \le 1\,250$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}} + 2\times 10^{\frac{37-38\lg(f/500)}{-20}}\right)$

[a] PS NEXT at frequencies that correspond to calculated values of greater than 62,0 dB revert to a minimum requirement of 62,0 dB.

Table 8 – PS NEXT values for a channel at key frequencies

Frequency MHz	**Minimum PS NEXT** dB
	Class
	I
1	62,0
16	50,9
100	37,5
250	30,6
500	25,4
600	23,2
1 000	16,6
1 250	13,5

4.2.4 Attenuation to crosstalk ratio at the near-end (ACR-N)

4.2.4.1 Pair-to-pair ACR-N

ACR-N performance is dependent upon NEXT and IL, and is not an independent specification included for 25GBASE-T.

4.2.4.2 Power sum ACR-N (PS ACR-N)

PS ACR-N performance is dependent upon PS NEXT and IL, and is not an independent specification included for 25GBASE-T.

4.2.5 Attenuation to crosstalk ratio at the far-end (ACR-F).

4.2.5.1 Pair-to-pair ACR-F

The ACR-F of each pair combination of a channel is specified in Table 9. The limits shown in Table 10 are derived from the formula at key frequencies.

Table 9 – ACR-F for a channel

Class	**Frequency** MHz	**Minimum ACR-F** [a, b] dB
I	$1 \le f \le 1\,250$	$-20\lg\left(10^{\frac{79-20\lg(f)}{-20}}+2\times10^{\frac{83,1-20\lg(f)}{-20}}\right)$

[a] ACR-F at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.

[b] The ACR-F limit at frequencies that correspond to calculated values of greater than 65,0 dB revert to a minimum requirement of 65,0 dB.

Table 10 – ACR-F values for a channel at key frequencies

Frequency MHz	**Minimum ACR-F** dB
	Class
	I
1	65,0
16	47,9
100	32,0
250	24,0
500	18,0
600	16,4
1 000	12,0
1 250	10,0

4.2.5.2 Power sum ACR-F (PS ACR-F)

The PS ACR-F of each pair of a channel is specified in Table 11. The limits shown in Table 12 are derived from the formula at key frequencies.

Table 11 – PS ACR -F for a channel

Class	**Frequency** MHz	**Minimum PS ACR-F** [a, b] dB
I	$1 \le f \le 1\,250$	$-20\lg\left(10^{\frac{76-20\lg(f)}{-20}} + 2\times 10^{\frac{80{,}1-20\lg(f)}{-20}}\right)$

[a] PS ACR-F at frequencies that correspond to calculated PS FEXT values of greater than 67,0 dB are for information only.

[b] The PS ACR-F limit at frequencies that correspond to calculated values of greater than 62,0 dB revert to a minimum requirement of 62,0 dB.

Table 12 – PS ACR-F values for a channel at key frequencies

Frequency MHz	**Minimum PS ACR-F** dB
	Class
	I
1	62,0
16	44,9
100	29,0
250	21,0
500	15,0
600	13,4
1 000	9,0
1 250	7,0

4.2.6 Propagation delay

The propagation delay of each pair of a channel is specified in Table 13. The limits shown in Table 14 are derived from the formula at key frequencies.

Table 13 – Propagation delay for a channel

Class	Frequency MHz	Maximum propagation delay µs
I	$1 \leq f \leq 1\,250$	$0{,}3 \times \left(0{,}534 + 0{,}036/\sqrt{f}\right) + 2 \times 0{,}002\,5$

Table 14 – Propagation delay values for a channel at key frequencies

Frequency MHz	Maximum propagation delay µs
	Class
	I
0,1	–
1	0,176
16	0,168
100	0,166
250	0,166
500	0,166
600	0,166
1 000	0,166
1 250	0,166

4.2.7 Delay skew

The delay skew between all pairs of a channel is specified in Table 15.

Table 15 – Delay skew for a channel

Class	Frequency MHz	Maximum delay skew µs
I	$1 \leq f \leq 1\,250$	0,016 [a, b]

[a] This is the result of the calculation 0,045 × 0,3 + 2 × 0,001 25.

[b] Skew between any two channel pairs due to environmental conditions is specified to not vary by more than 3 ns within the channel delay skew requirement (this is met by design).

4.2.8 Unbalance attenuation and coupling attenuation

4.2.8.1 Unbalance attenuation, near-end

This parameter is not specified by ISO/IEC/IEEE 8802-3:2017/AMD3 for 25GBASE-T.

4.2.8.2 Coupling attenuation

This parameter is not specified by ISO/IEC/IEEE 8802-3:2017/AMD3 for 25GBASE-T.

4.2.9 Alien crosstalk

4.2.9.1 Power sum alien NEXT (PS ANEXT)

The PS ANEXT of each pair of a channel is specified by the formula in Table 16. The limits shown in Table 17 are derived from the formula at key frequencies.

The PS ANEXT requirement is specified for both ends of the channel.

Table 16 – PS ANEXT for a channel

Class	**Frequency** MHz	**Minimum PS ANEXT** dB
I [a]	$1 \leq f < 100$	$105 - 10\lg(f)$
	$100 \leq f \leq 1\,250$	$115 - 15\lg(f)$

[a] PS ANEXT at frequencies that correspond to calculated values of greater than 75,0 dB revert to a minimum requirement of 75,0 dB.

Table 17 – PS ANEXT values for a channel at key frequencies

Frequency MHz	**Minimum PS ANEXT** dB
	Class
	I
1	75,0
100	75,0
250	75,0
500	74,5
1 000	70,0
1 250	68,5

4.2.9.2 Power sum alien ACR-F (PS AACR-F)

4.2.9.2.1 General

The PS AACR-F of each pair of a channel is specified to meet the requirements in Table 18. The limits shown in Table 19 are derived from the formula at key frequencies.

The PS AACR-F is specified for both ends of the channel.

The PS AACR-F is computed based on AFEXT, and insertion losses of disturbing and disturbed channels (see ISO/IEC 11801-1:2017, 6.3.3.13.4).

4.2.9.2.2 PS AFEXT

See ISO/IEC 11801-1:2017, 6.3.3.13.4 for an explanation of PS AFEXT calculations.

4.2.9.2.3 PS AACR-F

Table 18 – PS AACR-F for a channel

Class	Frequency MHz	Minimum PS AACR-F [a] dB
I	$1 \leq f \leq 1\,250$	$101 - 20\lg(f)$
[a] PS AACR-F at frequencies that correspond to calculated values of greater than 75,0 dB revert to a minimum requirement of 75,0 dB.		

Table 19 – PS AACR-F values for a channel at key frequencies

Frequency MHz	Minimum PS AACR-F dB
	Class
	I
1[a]	75,0
100	61,0
250	53,0
500	47,0
1 000	41,0
1 250	39,1
[a] PS AACR-F values at 1 MHz is affected by the computed insertion loss.	

4.3 Associated risk of 25GBASE-T operation over installed cabling

Table 20 shows the risk associated with 25GBASE-T operation over installed cabling channels.

Table 20 – Risk of 25GBASE-T operation over installed cabling channels

Channel type	Channel length [a]		
Component category	< 10 m	10 m to 20 m	20 m to 30 m
7_A	Low	Low	Low
7	Medium	High	High
6_A	Medium	High	High
[a] Risk level is based on meeting performance requirements of 4.1.			

4.4 Characterization of balanced channels using Category 7_A components

4.4.1 General

For channels made out of Category 7_A components, the support of 25GBASE-T requires compliance to channel requirements exceeding the original class specifications. Before qualification is started, the manufacturer should be consulted to determine whether the installed cable is rated up to 1 250 MHz.

Compared to Class F_A channels, 25GBASE-T has an upper frequency range 1 250 MHz and has more stringent requirements for insertion loss, return loss, alien crosstalk, propagation delay, delay skew and coupling attenuation as defined below.

Other parameters like NEXT, PS NEXT, ACR-N, PS ACR-N, ACR-F, PS ACR-F need to be validated to a higher upper frequency range of 1 000 MHz to 1 250 MHz.

4.4.2 Selection of channels for qualification

Channels made out of Category 7_A components may support 25GBASE-T up to 30 m. Before testing, test reports should be consulted to find channels which do have a length up to 30 m and sufficient RL margin. Those channels should be investigated further. Longer channels might be assessed too, but failure is likely.

Tests required for channels up to and including 30 m:

- For internal parameters: Retest all parameters given in 4.4.3 to 4.4.7, 4.4.9 and 4.4.10 from 1 MHz to 1 250 MHz.
- For coupling attenuation: Contact the manufacturer for a test report demonstrating the compliance of a channel made out of identical components with requirements of 4.4.11.
- For alien crosstalk: If a coupling attenuation test report is available and shows compliance to 4.4.12, alien crosstalk verification is not required. Otherwise execute alien crosstalk field testing according to IEC 61935-1.

4.4.3 Return loss

The return loss for each pair of a two-connector channel is specified to meet the limits computed using the formulae of Table 21. The limits shown in Table 22 are derived from the formulae at key frequencies.

Table 21 – Formulae for return loss limits for a channel

Frequency MHz	Minimum return loss dB
$1 \le f < 10$	19,0
$10 \le f < 40$	$24 - 5\log(f)$
$40 \le f < 130$	16
$130 \le f < 1000$	$35 - 9\log(f)$
$1000 \le f \le 1250$	8

Table 22 – Return loss limits for a channel at key frequencies

Frequency MHz	Minimum return loss dB
1,0	19,0
16,0	18,0
100,0	16,0
250,0	13,4
500,0	10,7
600,0	10,0
1 000,0	8,0
1 250,0	8,0

4.4.4 Insertion loss

The insertion loss for each pair of a two-connector channel is specified to not exceed the limits computed using the formula of Table 23. The limits shown in Table 24 are derived from the formula at key frequencies.

Table 23 – Formula for insertion loss limits for a channel

Frequency MHz	Maximum insertion loss [a] dB
$1 \leq f \leq 1\,250$	$0{,}32\left(1{,}8\sqrt{f}+0{,}005f+0{,}25/\sqrt{f}\right)+2\times 0{,}02\sqrt{f}$

[a] Values below 4 dB revert to 4 dB.

Table 24 – Insertion loss limits for a channel at key frequencies

Frequency MHz	Maximum insertion loss dB
1,0	4,0
16,0	4,0
100,0	6,3
250,0	10,1
500,0	14,6
600,0	16,1
1 000,0	21,1
1 250,0	23,8

4.4.5 Near-end crosstalk loss (NEXT)

4.4.5.1 Pair-to-pair NEXT

The pair-to-pair NEXT for each pair combination of a channel is specified to meet the limits computed using the formulae of Table 25. The limits shown in Table 26 are derived from the formulae at key frequencies. The length dependency of cables and channels is neglected because it affects only low frequencies.

Table 25 – Formulae for pair-to-pair NEXT limits for a channel

Frequency MHz	Minimum pair-to-pair NEXT [a, b] dB
$1 \leq f \leq 1\,000$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}}+2\times 10^{\frac{116{,}3-20\lg(f)}{-20}}\right)$
$1\,000 \leq f \leq 1\,250$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}}+2\times 10^{\frac{56{,}3-90\lg(f/1000)}{-20}}\right)$

[a] NEXT at frequencies that correspond to calculated values of greater than 65,0 dB revert to a minimum requirement of 65,0 dB.

[b] Whenever the channel insertion loss at 900 MHz is less than 17 dB, subtract the term $2{,}8((f-900)/100)$ from the formula stated above for the range of 900 MHz to 1 250 MHz, but not less than 30 dB (NEXT values smaller than 30 dB revert to a minimum requirement of 30 dB).

Table 26 – Pair-to-pair NEXT limits for a channel at key frequencies

Frequency MHz	Minimum pair-to-pair NEXT dB
1,0	65,0
16,0	65,0
100,0	65,0
250,0	59,1
500,0	53,6
600,0	52,1
1 000,0	47,9
1 250,0	40,5

4.4.5.2 Power sum NEXT (PS NEXT)

The PS NEXT for each pair combination of a channel is specified to meet the limits computed, to one decimal place, using the formulae of Table 27. The limits shown in Table 28 are derived from the formulae at key frequencies. The length dependency of cables and channels is neglected because it affects only low frequencies.

Table 27 – Formulae for PS NEXT limits for a channel

Frequency MHz	Minimum PS NEXT [a, b] dB
$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}}+2\times10^{\frac{113{,}3-20\lg(f)}{-20}}\right)$
$1\,000 \le f \le 1\,250$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}}+2\times10^{\frac{53{,}3-90\lg(f/1000)}{-20}}\right)$

[a] PS NEXT at frequencies that correspond to calculated values of greater than 62,0 dB revert to a minimum requirement of 62,0 dB.

[b] Whenever the channel insertion loss at 900 MHz is less than 17 dB, subtract the term 2,8((*f* – 900)/100) from the formula stated above for the range of 900 MHz to 1 250 MHz, but not less than 27 dB (PS NEXT values smaller than 27 dB revert to a minimum requirement of 27 dB).

Table 28 –PS NEXT limits for a channel at key frequencies

Frequency MHz	Minimum PS NEXT dB
1,0	62,0
16,0	62,0
100,0	62,0
250,0	56,1
500,0	50,6
600,0	49,1
1 000,0	44,9
1 250,0	37,5

4.4.6 Attenuation to crosstalk loss ratio near-end (ACR-N)

4.4.6.1 General

ACR-N performance is dependent upon NEXT and IL, and is not an independent specification included for 25GBASE-T.

4.4.6.2 Pair-to-pair ACR-N

The ACR-N for each pair combination of a channel is specified to meet the limits computed according to Equation (1), to one decimal place. The limits shown in Table 29 are derived from Equation (1) at key frequencies. The requirement is automatically satisfied when both insertion loss and NEXT requirements are met.

The ACR-N requirement is specified to be met at both ends of the cabling.

ACR-N_{ik} of pairs i and k is computed as follows:

$$\text{ACR-N}_{ik} = \text{NEXT}_{ik} - \text{IL}_k \text{ dB} \tag{1}$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

NEXT_{ik} is the near-end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of disturbed pair k. When required, it should be measured according to IEC 61935-1.

Table 29 – ACR-N limits for a channel at key frequencies

Frequency MHz	**Minimum ACR-N** dB
1,0	61,0
16,0	61,0
100,0	58,7
250,0	49,0
500,0	39,0
600,0	36.0
1 000,0	26,8
1 250,0	16,7

4.4.6.3 Power sum ACR-N (PS ACR-N)

PS ACR-N performance is dependent upon PS NEXT and IL, and is not an independent specification included for 25GBASE-T.

The PS ACR for each pair of a channel is specified to meet the limits computed according to Equation (2), to one decimal place. The limits shown in Table 30 are derived with Equation (2) at key frequencies. The requirement is automatically satisfied when both insertion loss and PS NEXT requirements are met.

PS ACR-N_k of pair k is computed as follows:

$$\text{PS ACR-N}_k = \text{PS NEXT}_k - \text{IL}_k \ \text{dB} \tag{2}$$

where

k is the number of the disturbed pair;

PS $NEXT_k$ is the power sum near-end crosstalk loss of pair k;

IL_k is the insertion loss of pair k. When required, it should be measured according to IEC 61935-1.

The PS ACR-N requirement is specified for both ends of the cabling.

Table 30 – PS ACR-N limits for a channel at key frequencies

Frequency MHz	**Minimum PS ACR-N** dB
1,0	58,0
16,0	58,0
100,0	55,7
250,0	46,0
500,0	36,0
600,0	33.0
1 000,0	23,8
1 250,0	13,7

4.4.7 Attenuation to crosstalk ratio far-end (ACR-F)

4.4.7.1 Pair-to-pair ACR-F

The ACR-F for each pair combination of a channel is specified to meet the limits computed using the formulae of Table 31. The limits shown in Table 32 are derived from the formulae at key frequencies.

Table 31 – Formulae for ACR-F limits for a channel

Frequency MHz	**Minimum ACR-F** [a, b] dB
$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{95,3-20\lg(f)}{-20}}+4\times10^{\frac{103,9-20\lg(f)}{-20}}\right)$ 65 maximum
$1\,000 \le f \le 1\,250$	$-20\lg\left(10^{\frac{95,3-20\lg(f)}{-20}}+4\times10^{\frac{43,9-90\lg(f/1000)}{-20}}\right)$

[a] ACR-F at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.

[b] The ACR-F limit at frequencies that correspond to calculated values of greater than 65,0 dB revert to a minimum requirement of 65,0 dB.

Table 32 – ACR-F limits for a channel at key frequencies

Frequency MHz	Minimum ACR-F dB
1,0	65,0
16,0	63,3
100,0	47,7
250,0	39,4
500,0	33,4
600,0	31,8
1 000,0	27,4
1 250,0	20,8

4.4.7.2 Power sum ACR-F (PS ACR-F)

The PS ACR-F for each pair combination of a channel is specified to meet the limits computed using the formulae of Table 33. The limits shown in Table 34 are derived from the formulae at key frequencies.

Table 33 – Formulae for PS ACR-F limits for a channel

Frequency MHz	Minimum PS ACR-F [a, b] dB
$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{92,3-20\lg(f)}{-20}}+4\times10^{\frac{100,9-20\lg(f)}{-20}}\right)$
$1\,000 \le f \le 1\,250$	$-20\lg\left(10^{\frac{92,3-20\lg(f)}{-20}}+4\times10^{\frac{40,9-90\lg(f/1000)}{-20}}\right)$

[a] PS ACR-F at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.

[b] The PS ACR-F limit at frequencies that correspond to calculated values of greater than 62,0 dB revert to a minimum requirement of 62,0 dB.

Table 34 – PS ACR-F limits for a channel at key frequencies

Frequency MHz	Minimum PS ACR-F dB
1,0	62,0
16,0	60,3
100,0	44,4
250,0	36,4
500,0	30,4
600,0	28,8
1 000,0	24,4
1 250,0	17,8

4.4.8 Alien (exogenous) crosstalk

4.4.8.1 PS ANEXT

The PS ANEXT for each pair combination of a channel is specified to meet the limits computed using the formulae of Table 35. The limits shown in Table 36 are derived from the formulae at key frequencies.

Table 35 – Formulae for PS ANEXT limits for a channel

Frequency MHz	Minimum PS ANEXT [a] dB
$1 \leq f < 100$	$105 - 10\lg(f)$
$100 \leq f < 1\,250$	$115 - 15\lg(f)$

[a] PS ANEXT at frequencies that correspond to calculated values of greater than 75,0 dB revert to a minimum requirement of 75,0 dB.

Table 36 – PS ANEXT limits for a channel at key frequencies

Frequency MHz	Minimum PS ANEXT dB
1,0	75
16,0	75
100,0	75
250,0	75
500,0	74,5
600,0	73,3
1 000,0	70,0
1 250,0	68,5

4.4.8.2 PS AACR-F

The PS AACR-F for each pair combination of a channel is specified to meet the limits computed using the formula of Table 37. The limits shown in Table 38 are derived from the formula at key frequencies.

Table 37 – Formula for PS AACR-F limits for a channel

Frequency MHz	Minimum PS AACR-F [a, b] dB
$1 \leq f < 1\,250$	$101 - 20\lg(f)$

[a] PS AACR-F at frequencies that correspond to calculated PS AFEXT values of greater than 67,0 dB or $102 - 15\lg(f)$ dB are for information only.

[b] PS AACR-F at frequencies that correspond to calculated values of greater than 75,0 dB revert to a minimum requirement of 75,0 dB.

Table 38 – PS AACR-F limits for a channel at key frequencies

Frequency MHz	Minimum PS AACR-F dB
1,0	75,0
16,0	75,0
100,0	61,0
250,0	53,0
500,0	47,0
600,0	45,4
1 000,0	41,0
1 250,0	39,1

4.4.9 Propagation delay

The propagation delay for each pair of a channel is specified to not exceed the limits computed, to three decimal places, using the formula of Table 39. The limits shown in Table 40 are derived from the formula at key frequencies.

Table 39 – Formula for propagation delay limits for a channel

Frequency MHz	Maximum propagation delay µs
$1 \leq f < 1250$	$0{,}3 \times (0{,}534 + 0{,}036/\sqrt{(f)}) + 2 \times 0{,}0025$

Table 40 – Propagation delay limits for a channel at key frequencies

Frequency MHz	Maximum propagation delay µs
1,0	0,176
16,0	0,168
100,0	0,166
250,0	0,166
500,0	0,166
600,0	0,166
1 000,0	0,166
1 250,0	0,165

4.4.10 Delay skew

The skew between all pairs of a channel is specified to not exceed 0,010 µs.

4.4.11 Coupling attenuation

The coupling attenuation for each pair of a shielded channel is specified to meet the limits computed using the formula of Table 41. The limits shown in Table 42 are derived from the formula at key frequencies.

Table 41 – Formula for coupling attenuation limits for a channel

Frequency MHz	**Minimum coupling attenuation** dB
$30 \leq f \leq 100$	50
$100 \leq f \leq 1\,250$	$90 - 20\lg(f)$

Table 42 – Coupling attenuation limits for a channel at key frequencies

Frequency MHz	**Minimum coupling attenuation** dB
1,0	N/A
16,0	N/A
100,0	50,0
250,0	42,0
500,0	36,0
600,0	34,4
1 000,0	30,0
1 250,0	28,1

4.4.12 Alien crosstalk and coupling attenuation

When coupling attenuation for a channel meets or exceeds the value of Table 43, the PS ANEXT limits are met.

When coupling attenuation for a channel meets or exceeds the values of Table 43, the PS AACR-F limits are met.

Table 43 – Alien crosstalk and coupling attenuation

Frequency MHz	**Minimum coupling attenuation to meet PS ANEXT limits** dB	**Minimum coupling attenuation to meet PS AACR-F limits** dB
$30 \leq f \leq 100$	65	65
$100 \leq f \leq 1\,250$	$105 - 20\lg(f)$	$105 - 20\lg(f)$

4.5 Characterization of balanced channels using Category 7 components

4.5.1 General

For channels made out of Category 7 components, the support of 25GBASE-T requires compliance to channel requirements exceeding the Class F specifications. Compared to Class F channels, 25GBASE-T has more stringent requirements for insertion loss, return loss, alien crosstalk, propagation delay, delay skew and coupling attenuation as defined below.

Other parameters like NEXT, PS NEXT, ACR-F, PS ACR-F need to be validated to a higher upper frequency range of 600 MHz to 1 250 MHz.

When component behaviour in the additional frequency range, namely insertion loss, return loss and alien crosstalk, is not adequate, some installed cabling channels at shorter length might still be able to meet the requirements contained in ISO/IEC/IEEE 8802-3:2017/AMD3 for 25GBASE-T application.

4.5.2 Selection of channels for qualification

Channels made out of Category 7 components may support 25GBASE-T up to 12 m. Before testing, existing channel test reports should be consulted to find channels, which do have a length up to 12 m and sufficient RL margin up to 600 MHz. Those channels should be investigated further. Longer channels might be assessed too, but failure is likely.

Tests required for channels up to and including 12 m:

- For internal parameters: Retest all parameters from 4.5.3 to 4.5.7 and 4.5.9 and 4.5.10 from 1 MHz to 1250 MHz.
- For coupling attenuation: Contact the manufacturer for a test report demonstrating the compliance of a channel made out of identical components with requirements of 4.5.11.
- For alien crosstalk: If a coupling attenuation test report is available and shows compliance to 4.5.12, alien crosstalk verification is not required. Otherwise execute alien crosstalk field testing according to IEC 61935-1.

4.5.3 Return loss

The return loss for each pair of a two-connector channel is specified to meet the limits computed using the formulae of Table 44. The limits shown in Table 45 are derived from the formulae at key frequencies.

Table 44 – Formulae for return loss limits for a channel

Frequency MHz	Minimum return loss dB
$1 \le f < 10$	19,0
$10 \le f < 40$	$24 - 5\log(f)$
$40 \le f < 130$	16
$130 \le f < 1\,000$	$35 - 9\log(f)$
$1\,000 \le f \le 1\,250$	8

Table 45 – Return loss limits for a channel at key frequencies

Frequency MHz	Minimum return loss dB
1,0	19,0
16,0	18,0
100,0	16,0
250,0	13,4
500,0	10,7
600,0	10,0
1 000,0	8,0
1 250,0	8,0

4.5.4 Insertion loss

The insertion loss for each pair of a two-connector channel is specified to not exceed the limits computed using the formula of Table 46. The limits shown in Table 47 are derived from the formula at key frequencies.

Table 46 – Formula for insertion loss limits for a channel

Frequency MHz	**Maximum insertion loss** dB
$1 \leq f \leq 1\,250$	$0,32\left(1,8\sqrt{f}+0,005f+0,25/\sqrt{f}\right)+2\times 0,02\sqrt{f}$
NOTE Values below 4 dB revert to 4 dB.	

Table 47 – Insertion loss limits for a channel at key frequencies

Frequency MHz	**Maximum insertion loss** dB
1,0	4,0
16,0	4,0
100,0	6,3
250,0	10,1
500,0	14,6
600,0	16,1
1 000,0	21,1
1 250,0	23,8

4.5.5 Near-end crosstalk loss (NEXT)

4.5.5.1 Pair-to-pair NEXT

The pair-to-pair NEXT for each pair combination of a channel is specified to meet the limits computed using the formulae of Table 48. The limits shown in Table 49 are derived from the formulae at key frequencies. The length dependency of cables and channels is neglected because it affects only low frequencies.

Table 48 – Formulae for pair-to-pair NEXT limits for a channel

Frequency MHz	**Minimum pair-to-pair NEXT** [a] dB
$1 \leq f \leq 600$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}}+2\times 10^{\frac{102,4-20\lg(f)}{-20}}\right)$
$600 \leq f \leq 1\,250$	$-20\lg\left(10^{\frac{75,3-15\lg(f)}{-20}}+2\times 10^{\frac{40-38\lg(f/500)}{-20}}\right)$
[a] NEXT at frequencies that correspond to calculated values of greater than 65,0 dB revert to a minimum requirement of 65,0 dB.	

Table 49 – Pair-to-pair NEXT limits for a channel at key frequencies

Frequency MHz	Minimum pair-to-pair NEXT dB
1,0	65,0
16,0	65,0
100,0	65,0
250,0	56,9
500,0	52,4
600,0	51,2
1 000,0	19,6
1 250,0	16.5

4.5.5.2 Power sum NEXT (PS NEXT)

The PS NEXT for each pair combination of a channel is specified to meet the limits computed, to one decimal place, using the formulae of Table 50. The limits shown in Table 51 are derived from the formulae at key frequencies. The length dependency of cables and channels is neglected because it affects only low frequencies.

Table 50 – Formulae for PS NEXT limits for a channel

Frequency MHz	Minimum PS NEXT [a] dB
$1 \leq f \leq 600$	$-20\lg\left(10^{\frac{99,4-15\lg(f)}{-20}}+2\times 10^{\frac{99,4-15\lg(f)}{-20}}\right)$
$600 \leq f \leq 1250$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}}+2\times 10^{\frac{37-38\lg(f/500)}{-20}}\right)$
[a] PS NEXT at frequencies that correspond to calculated values of greater than 62,0 dB revert to a minimum requirement of 62,0 dB.	

Table 51 – PS NEXT limits for a channel at key frequencies

Frequency MHz	Minimum PS NEXT dB
1,0	62,0
16,0	62,0
100,0	59,9
250,0	53,9
500,0	49,4
600,0	48,2
1 000,0	16,6
1 250,0	13,5

4.5.6 Attenuation to crosstalk loss ratio near-end (ACR-N)

4.5.6.1 Pair-to-pair ACR-N

The ACR-N for each pair combination of a channel is specified to meet the limits computed according to Equation (3), to one decimal place. The limits shown in Table 52 are derived from Equation (3) at key frequencies. The requirement is automatically satisfied when both insertion loss and NEXT requirements are met.

The ACR-N requirement is specified for both ends of the cabling.

ACR-N_{ik} of pairs i and k is computed as follows:

$$\text{ACR-N}_{ik} = \text{NEXT}_{ik} - \text{IL}_k \quad \text{dB} \qquad (3)$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

NEXT_{ik} is the near-end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of disturbed pair k. When required, it should be measured according to IEC 61935-1.

Table 52 – ACR-N limits for a channel at key frequencies

Frequency MHz	Minimum ACR-N dB
1,0	61,0
16,0	61,0
100,0	56,5
250,0	46,7
500,0	37,8
600,0	35,1
1 000,0	−1,5
1 250,0	−7,3

4.5.6.2 Power sum ACR-N (PS ACR-N)

The PS ACR-N for each pair of a channel is specified to meet the limits computed according to Equation (4), to one decimal place. The limits shown in Table 53 are derived with Equation (4) at key frequencies. The requirement is automatically satisfied when both insertion loss and PS NEXT requirements are met.

PS ACR-N_k of pair k is computed as follows:

$$\text{PS ACR-N}_k = \text{PS NEXT}_k - \text{IL}_k \quad \text{dB} \qquad (4)$$

where

k is the number of the disturbed pair;

PS NEXT_k is the power sum near-end crosstalk loss of pair k;

IL_k is the insertion loss of pair k. When required, it should be measured according to IEC 61935-1.

The PS ACR-N requirement is specified for both ends of the cabling.

Table 53- PS ACR-N limits for a channel at key frequencies

Frequency MHz	Minimum PS ACR-N dB
1,0	58,0
16,0	58,0
100,0	53,4
250,0	43,7
500,0	34,8
600,0	32,1
1 000,0	−4,5
1 250,0	−10,3

4.5.7 Attenuation to crosstalk ratio far-end (ACR-F)

4.5.7.1 Pair-to-pair ACR-F

The ACR-F for each pair combination of a channel is specified to meet the limits computed using the formulae of Table 54. The limits shown in Table 55 are derived from the formulae at key frequencies.

Table 54 – Formulae for ACR-F limits for a channel

Frequency MHz	Minimum ACR-F [a, b] dB
$1 \le f \le 600$	$-20\lg\left(10^{\frac{94-20\lg(f)}{-20}} + 4\times 10^{\frac{90-15\lg(f)}{-20}}\right)$ 65 maximum
$600 \le f \le 1\,250$	$-20\lg\left(10^{\frac{79-20\lg(f)}{-20}} + 2\times 10^{\frac{83,1-20\lg(f)}{-20}}\right)$

[a] ACR-F at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.

[b] The ACR-F limit at frequencies that correspond to calculated values of greater than 65,0 dB revert to a minimum requirement of 65,0 dB.