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INTERNATIONAL STANDARD

AMENDMENT 1

Information technology – Generic cabling for customer premises

ISO/IEC 11801 A1:2008(E)

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Information technology –
Generic cabling for customer premises

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FOREWORD

Amendment 1 to International Standard ISO/IEC 11801:2002 was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

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

The contents of Corrigendum 1 published in September 2008 has been included in this copy.

INTRODUCTION to Amendment 1

This amendment provides requirements for new Class E_A and F_A channels plus additions and corrections to ISO/IEC 11801:2002. Amendment 2 of ISO/IEC 11801:2002 will provide balanced cabling models, requirements and normative references for Category 6_A and 7_A components, requirements for Class E_A and F_A links, together with amendments to the requirements for optical fibre cabling.

Update references to Tables, the numbers of which have been changed.

Page 6

Replace, in the list of figures, the title of Figure 10 by the following new title:

Figure 10 – Balanced cabling: channel, permanent link and CP link.

Page 13

2 Normative references

Replace, on page 14 to 17, the following references by the updated references as indicated below:

IEC 60512-25-5, *Connectors for electronic equipment – Basic tests and measurements – Part 25-5: Test 25e – Return loss*[1]

IEC/PAS 60793-1-49:2002, *Optical fibres – Part 1-49: Measurement methods and test procedures – Differential mode delay*

IEC 60794-2:1989, *Optical fibre cables – Part 2: Product specification (indoor cable)* [2]
Amendment 1 (1998)

IEC/PAS 61076-3-104:2002, *Connectors for electronic equipment – Part 3-104: Detail specification for 8-way, shielded free and fixed connectors, for data transmissions with frequencies up to 600 MHz*

IEC 61935-1:2000, *Generic cabling systems – Specifications for the testing of balanced communication cabling in accordance with ISO/IEC 11801 – Part 1: Installed cabling*
Amendment 1 (under consideration)

IEC 61935-2, *Generic cabling systems – Specification for the testing of balanced communication cabling in accordance with ISO/IEC 11801 – Part 2: Patch cords and work area cords*[1)]

ISO/IEC TR 14763-1, *Information technology – Implementation and operation of customer premises cabling – Part 1: Administration*

ISO/IEC 18010:2002, *Information technology – Pathways and spaces for customer premises cabling*

Updated references:

IEC 60512-25-5, *Connectors for electronic equipment – Tests and measurements – Part 25-5: Test 25e – Return loss*

1 To be published.

2 There exists a consolidated Edition 4.1 (1998) of IEC 60794-2 that includes Edition 4.0 (1989) and its amendment 1 (1998).

IEC 60793-1-49, *Optical fibres – Part 1-49: Measurement methods and test procedures – Differential mode delay*

IEC 60794-2, *Optical fibre cables – Part 2: Indoor cables – Sectional specification*

IEC 61076-3-104, *Connectors for electronic equipment – Product requirements – Part 3-104: Detail specification for 8-way, shielded free and fixed connectors for data transmissions with frequencies up to 600 MHz minimum*[3]

IEC 61935-1, *Testing of balanced communication cabling in accordance with ISO/IEC 11801 – Part 1: Installed cabling*)

IEC 61935-2, *Testing of balanced communication cabling in accordance with ISO/IEC 11801 – Part 2: Patch cords and work area cords*

ISO/IEC 14763-1, *Information technology – Implementation and operation of customer premises cabling – Part 1: Administration*

ISO/IEC 18010, *Information technology – Pathways and spaces for customer premises cabling*

Page 17

3 Definitions, abbreviations and symbols

3.1 Definitions

Replace the existing titles by the following new titles:

3 Terms and definitions, abbreviations and symbols

3.1 Terms and definitions

Page 20

3.1.35
Replace the existing term number, term, definition and NOTE *by the following new term number, term, definition and* NOTE*:*

3.1.45
insertion loss
loss incurred by inserting a device between a source and load of equal impedance. The device itself may have a different impedance from the load and source impedance

NOTE The terms operational attenuation or operational insertion loss are sometimes associated with this definition.

3.1.36
Replace the existing term number and definition by the following new term number and definition:

3.1.46
insertion loss deviation
difference between the measured insertion loss of cascaded components and the insertion loss determined by the sum of the individual component insertion losses

3 A new edition (edition 3.0) to support measurements up to 1 000 MHz is under consideration.

Page 21

3.1.41

Replace the existing term number and definition by the following new term number and definition:

3.1.51

link

transmission path between two cabling system interfaces, including the connections at each end

Pages 17 to 23

***Insert**, in the existing list of terms and definitions, the following new terms and definitions in alphabetical order and renumber the existing terms and definitions accordingly:*

3.1.2

alien (exogenous) crosstalk

signal coupling from a disturbing pair of a channel to a disturbed pair of another channel

NOTE This also applies to the signal coupling from a disturbing pair within a permanent link or component, used to create a channel, to a disturbed pair within a permanent link or component, used to create another channel.

3.1.3

alien (exogenous) far-end crosstalk loss (AFEXT)

signal isolation between a disturbing pair of a channel and a disturbed pair of another channel, measured at the far-end

NOTE This also applies to the measurement of the signal isolation between a disturbing pair within a permanent link or component, used to create a channel, and a disturbed pair within a permanent link or component, used to create another channel.

3.1.4

alien (exogenous) near-end crosstalk loss (ANEXT)

signal isolation between a disturbing pair of a channel and a disturbed pair of another channel, measured at the near-end

NOTE This also applies to the measurement of signal isolation between a disturbing pair within a permanent link or component, used to create a channel, and a disturbed pair within a permanent link or component, used to create another channel.

3.1.7

attenuation to alien (exogenous) crosstalk ratio at the far-end (AACR-F)

difference, in dB, between the alien far-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair in another channel

NOTE This also applies to the calculation using the alien far-end crosstalk loss from a disturbing pair within a permanent link or component, used to create a channel, and the insertion of a disturbed pair within a permanent link or component, used to create another channel.

3.1.8

attenuation to alien (exogenous) crosstalk ratio at the near-end (AACR-N)

difference, in dB, between the alien near-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair in another channel

NOTE This also applies to the calculation using the alien near-end crosstalk loss from a disturbing pair within a permanent link or component, used to create a channel, and the insertion loss of a disturbed pair within a permanent link or component, used to create another channel.

3.1.9

attenuation to crosstalk ratio at the far-end (ACR-F)

difference, in dB, between the far-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair of the same channel

NOTE This also applies to the calculation using the far-end crosstalk loss from a disturbing pair within a permanent link or component, used to create a channel, and the insertion loss of a disturbed pair within the permanent link or component, of the same channel.

3.1.10
attenuation to crosstalk ratio at the near-end (ACR-N)
difference, in dB, between the near-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair of the same channel

NOTE This also applies to the calculation using the near-end crosstalk loss from a disturbing pair within a permanent link or component, used to create a channel, and the insertion loss of a disturbed pair within the permanent link or component, of the same channel.

3.1.11
average power sum alien (exogenous) near-end crosstalk loss
the calculated average of the power sum alien near-end crosstalk loss of the pairs of a disturbed channel

NOTE This also applies to the calculation using the pairs within a permanent link used to create a channel.

3.1.12
average power sum attenuation to alien (exogenous) crosstalk ratio far-end
the calculated average of the power sum attenuation to alien crosstalk ratio at the far-end of the pairs of a disturbed channel

NOTE This also applies to the calculation using the pairs within a permanent link used to create a channel.

3.1.35
equal level far-end crosstalk ratio (ELFEXT)
difference, in dB, between the far-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbing pair of the same channel

NOTE This also applies to the calculation using the far-end crosstalk loss from a disturbing pair within a permanent link or component, used to create a channel, and the insertion loss of a disturbing pair within a permanent link or component, of the same channel.

3.1.55
operating temperature
stabilised temperature of the cabling combining ambient temperature with any increase due to the application being supported

3.1.64
power sum alien (exogenous) far-end crosstalk loss (PS AFEXT)
power sum of the signal isolation between multiple disturbing pairs of one or more channels and a disturbed pair of another channel, measured at the far-end

NOTE This also applies to the calculation using the multiple disturbing pairs within one or more permanent links or components and a disturbed pair within a permanent link or component, used to create another channel.

3.1.65
power sum alien (exogenous) near-end crosstalk loss (PS ANEXT)
power sum of the signal isolation between multiple disturbing pairs of one or more channels and a disturbed pair of another channel, measured at the near-end

NOTE This also applies to the calculation using the multiple disturbing pairs within one or more permanent links or components and a disturbed pair within a permanent link or component, used to create another channel.

3.1.66
power sum attenuation to alien (exogenous) crosstalk ratio at the far-end (PS AACR-F)
difference, in dB, between the power sum alien far-end crosstalk loss from multiple disturbing pairs of one or more channels and the insertion loss of a disturbed pair in another channel

NOTE This also applies to the calculation using the power sum alien far-end crosstalk loss from multiple disturbing pairs within one or more permanent links or components and the insertion loss of a disturbed pair within a permanent link or component, used to create another channel.

3.1.67
power sum attenuation to alien (exogenous) crosstalk ratio at the near-end (PS AACR-N)
difference, in dB, between the power sum alien near-end crosstalk loss from multiple disturbing pairs of one or more channels and the insertion loss of a disturbed pair in another channel

NOTE This also applies to the calculation using the power sum alien near-end crosstalk loss from multiple disturbing pairs within one or more permanent links or components, and the insertion loss of a disturbed pair within a permanent link or component, used to create another channel.

3.1.68
power sum attenuation to crosstalk ratio at the far-end (PS ACR-F)
difference, in dB, between the power sum far-end crosstalk loss from multiple disturbing pairs of a channel and the insertion loss of a disturbed pair in the same channel

NOTE This also applies to the calculation using the power sum far-end crosstalk loss from multiple disturbing pairs within one or more permanent links or components, used to create a channel, and the insertion loss of a disturbed pair within a permanent link or component, of the same channel.

3.1.69
power sum attenuation to crosstalk ratio at the near-end (PS ACR-N)
difference, in dB, between the power sum near-end crosstalk loss from multiple disturbing pairs of a channel and the insertion loss of a disturbed pair in the same channel

NOTE This also applies to the calculation using the multiple disturbing pairs within one or more permanent links or components, used to create a channel, and the insertion loss of a disturbed pair within a permanent link or component, of the same channel.

3.1.70
power sum equal level far-end crosstalk ratio (PS ELFEXT)
power sum of all disturbing pairs of a channel, of the difference, in dB, between the far-end crosstalk loss and the insertion loss of each disturbing pair

NOTE This also applies to the calculation using the multiple disturbing pairs within one or more permanent links or components, used to create a channel, and the insertion loss of a disturbing pair within a permanent link or component, of the same channel.

Update the reference numbers to the terms and definitions throughout the document.

Pages 23 to 24

3.2 Abbreviations

Replace the existing items as follows:

ISO	International Standardisation Organisation
ELFEXT	Equal level far-end crosstalk attenuation (loss)
PS NEXT	Power sum NEXT attenuation (loss)
PS ELFEXT	Power sum ELFEXT attenuation (loss)
PS FEXT	Power sum FEXT attenuation (loss)

by the following amended items:

ELFEXT	Equal level FEXT
ISO	International Organization for Standardization
PS ELFEXT	Power sum ELFEXT
PS FEXT	Power sum FEXT (loss)
PS NEXT	Power sum NEXT (loss)

Insert, in the existing Table, the following new abbreviations in alphabetical sequence:

AACR-F	Attenuation to alien crosstalk ratio at the far-end
ACR-F	Attenuation to crosstalk ratio at the far-end
ACR-N	Attenuation to crosstalk ratio at the near-end
AFEXT	Alien far-end crosstalk (loss)
ANEXT	Alien near-end crosstalk (loss)
ELTCTL	Equal level TCTL
PS AACR-F	Power sum attenuation to alien crosstalk ratio at the far-end
PS AACR-F_{avg}	Average power sum attenuation to alien crosstalk ratio at the far-end
PS ACR-F	Power sum attenuation to crosstalk ratio at the far-end
PS ACR-N	Power sum attenuation to crosstalk ratio at the near-end
PS AFEXT	Power sum alien far-end crosstalk (loss)
PS $AFEXT_{norm}$	Normalized power sum alien far-end crosstalk (loss)
PS ANEXT	Power sum alien near-end crosstalk (loss)
PS $ANEXT_{avg}$	Average power sum alien near-end crosstalk (loss)

Pages 24 and 25

3.3.1 Variables

Insert, in the existing list, the following new variables in alphabetical order:

l number of the disturbing channel

N number of disturbing channels

Page 25

3.3.2 Indices

Insert, in the existing list, the following new indices in alphabetical order:

avg index to denominate average of the associated parameter across all of the pairs in the same channel or permanent link

norm index to denominate scaling of the associated parameter

Page 25

4 Conformance

Replace the entire text of this clause by the following text.

For a cabling installation to conform to this International Standard the following applies.

a) The configuration and structure shall conform to the requirements outlined in Clause 5.

b) The performance of balanced channels shall meet the requirements specified in Clause 6.

This shall be achieved by one of the following:

1) a channel design and implementation ensuring that the prescribed channel performance is met;
2) attachment of appropriate components to a permanent link or CP link design meeting the prescribed performance class of Clause 6 and Annex A. Channel performance shall be assured where a channel is created by adding more than one cord to either end of a link meeting the requirements of Clause 6 and Annex A;
3) using the reference implementations of Clause 7 and compatible cabling components conforming to the requirements of Clauses 9, 10 and 13, based upon a statistical approach of performance modelling.

Until amendment 2[4] of ISO/IEC 11801:2002 has been published:

- conformance for Classes D, E and F with regards to TCL, ELTCTL and coupling attenuation can only be achieved by option 1) above;
- conformance for Classes E_A and F_A can only be achieved by option 1) above.

c) The implementation and performance of optical fibre cabling channels shall meet the requirements specified in Clause 8.

d) The interfaces to the cabling at the TO shall conform to the requirements of Clause 10 with respect to mating interfaces and performance.

e) Connecting hardware at other places in the cabling structure shall meet the performance requirements specified in Clause 10.

f) If present, screens shall be handled as specified in Clause 11.

g) System administration shall meet the requirements of Clause 12.

h) Regulations on safety and EMC applicable at the location of the installation shall be met.

In the absence of the channel, the conformance of the link shall be used to verify conformance with the standard.

Specifications marked "f.f.s." are preliminary specifications, and are not required for conformance to this International Standard.

Page 30

5.5 Accommodation of functional elements

Replace the existing text of the last paragraph of this subclause by the following new text:

Telecommunications outlets are typically located in the work area.

[4] Amendment 2 to ISO/IEC 11801 is under consideration.

Page 37

Figure 10

Replace the title of this Figure by the following new title:

Figure 10 – Balanced cabling: channel, permanent link and CP link

Page 38

6.2 Layout

Replace the existing text of the third paragraph by the following new text and note:

The performance limits for balanced cabling channels are given in 6.4. These limits are derived from the component performance limits of Clause 9 and 10 using reference implementations specified in Clause 7.

NOTE Component performance requirements for Category 6_A and Category 7_A will be available in amendment 2 to ISO/IEC 11801:2002.

Replace, on page 39, the existing text of the first paragraph by the following new text:

The performance limits for balanced cabling permanent links and CP links are given in Annex A. These limits are derived from the component performance limits of Clauses 9 and 10 using reference implementations specified in Clause 7.

NOTE Permanent link and CP link requirements for Class E_A and Class F_A will be available in amendment 2 to ISO/IEC 11801:2002.

Page 39

6.3 Classification of balanced cabling

Replace, in the existing list, Class E and Class F by the following:

Class E is specified up to 250 MHz.

Class E_A is specified up to 500 MHz.

Class F is specified up to 600 MHz.

Class F_A is specified up to 1 000 MHz.

Page 39

6.4.1 General

Add, at the end of the second paragraph, the following new sentence:

For the purposes of this standard, insertion loss is measured with source and load impedances of 100 Ω.

Add, at the end of the third paragraph, the following new sentence:

When required for assessment, channels shall be measured according to IEC 61935-1, unless otherwise specified in this clause.

Page 39

6.4.2 Return loss

Replace, on page 40, the existing Tables 2 and 3, by the following new Tables 2 and 3:

Table 2 – Return loss for channel

Class	Frequency MHz	Minimum return loss dB
C	$1 \le f \le 16$	15,0
D	$1 \le f < 20$	17,0
	$20 \le f \le 100$	$30 - 10\lg(f)$
E	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\lg(f)$
	$40 \le f \le 250$	$32 - 10\lg(f)$
E_A	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\lg(f)$
	$40 \le f < 398.1$	$32 - 10\lg(f)$
	$398.1 \le f \le 500$	6,0
F	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\lg(f)$
	$40 \le f < 251,2$	$32 - 10\lg(f)$
	$251,2 \le f \le 600$	8,0
F_A	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\lg(f)$
	$40 \le f < 251,2$	$32 - 10\lg(f)$
	$251,2 \le f < 631$	8,0
	$631 \le f \le 1\,000$	$36 - 10\lg(f)$

Table 3 – Informative return loss values for channel at key frequencies

Frequency MHz	Minimum return loss dB					
	Class C	Class D	Class E	Class E_A	Class F	Class F_A
1	15,0	17,0	19,0	19,0	19,0	19,0
16	15,0	17,0	18,0	18,0	18,0	18,0
100	N/A	10,0	12,0	12,0	12,0	12,0
250	N/A	N/A	8,0	8,0	8,0	8,0
500	N/A	N/A	N/A	6,0	8,0	8,0
600	N/A	N/A	N/A	N/A	8,0	8,0
1 000	N/A	N/A	N/A	N/A	N/A	6,0

Page 40

6.4.3 Insertion loss/attenuation

Replace, on page 41, the existing Tables 4 and 5, by the following new Tables 4 and 5:

Table 4 – Insertion loss for channel

Class	Frequency MHz	Maximum insertion loss [a] dB
A	$f = 0,1$	16,0
B	$f = 0,1$	5,5
	$f = 1$	5,8
C	$1 \le f \le 16$	$1,05 \times \left(3,23\sqrt{f}\right) + 4 \times 0,2$
D	$1 \le f \le 100$	$1,05 \times \left(1,910\,8\sqrt{f} + 0,022\,2 \times f + 0,2/\sqrt{f}\right) + 4 \times 0,04 \times \sqrt{f}$
E	$1 \le f \le 250$	$1,05 \times \left(1,82\sqrt{f} + 0,016\,9 \times f + 0,25/\sqrt{f}\right) + 4 \times 0,02 \times \sqrt{f}$
E_A	$1 \le f \le 500$	$1,05 \times \left(1,82\sqrt{f} + 0,009\,1 \times f + 0,25/\sqrt{f}\right) + 4 \times 0,02 \times \sqrt{f}$
F	$1 \le f \le 600$	$1,05 \times \left(1,8\sqrt{f} + 0,01 \times f + 0,2/\sqrt{f}\right) + 4 \times 0,02 \times \sqrt{f}$
F_A	$1 \le f \le 1\,000$	$1,05 \times \left(1,8\sqrt{f} + 0,005 \times f + 0,25/\sqrt{f}\right) + 4 \times 0,02 \times \sqrt{f}$

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

Table 5 – Informative insertion loss values for channel at key frequencies

Frequency MHz	Maximum insertion loss dB							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
0,1	16,0	5,5	N/A	N/A	N/A	N/A	N/A	N/A
1	N/A	5,8	4,2	4,0	4,0	4,0	4,0	4,0
16	N/A	N/A	14,4	9,1	8,3	8,2	8,1	8,0
100	N/A	N/A	N/A	24,0	21,7	20,9	20,8	20,3
250	N/A	N/A	N/A	N/A	35,9	33,9	33,8	32,5
500	N/A	N/A	N/A	N/A	N/A	49,3	49,3	46,7
600	N/A	N/A	N/A	N/A	N/A	N/A	54,6	51,4
1 000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	67,6

Page 41

6.4.4.1 Pair-to-pair NEXT

Replace, on page 42, the existing Tables 6 and 7, by the following new Tables 6 and 7:

Table 6 – NEXT for channel

Class	**Frequency** MHz	**Minimum NEXT** [a] dB
A	$f = 0{,}1$	27,0
B	$0{,}1 \le f \le 1$	$25 - 15\lg(f)$
C	$1 \le f \le 16$	$39{,}1 - 16{,}4\lg(f)$
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{65{,}3-15\lg(f)}{-20}} + 2\times 10^{\frac{83-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{74{,}3-15\lg(f)}{-20}} + 2\times 10^{\frac{94-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{74{,}3-15\lg(f)}{-20}} + 2\times 10^{\frac{94-20\lg(f)}{-20}}\right)$ [b, d]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}} + 2\times 10^{\frac{102{,}4-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}} + 2\times 10^{\frac{116{,}3-20\lg(f)}{-20}}\right)$ [c, d]

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

[b] Whenever the Class E_A channel insertion loss at 450 MHz is less than 12 dB, subtract the term $1{,}4((f-450)/50)$ to the equation stated above for the range of 450 MHz to 500 MHz.

[c] Whenever the Class F_A channel insertion loss at 900 MHz is less than 17 dB, subtract the term $2{,}8((f-900)/100)$ to the equation stated above for the range of 900 MHz to 1 000 MHz.

[d] The terms in the equations are not intended to imply component performance.

Table 7 – Informative NEXT values for channel at key frequencies

Frequency MHz	Minimum channel NEXT dB							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
0,1	27,0	40,0	N/A	N/A	N/A	N/A	N/A	N/A
1	N/A	25,0	39,1	63,3	65,0	65,0	65,0	65,0
16	N/A	N/A	19,4	43,6	53,2	53,2	65,0	65,0
100	N/A	N/A	N/A	30,1	39,9	39,9	62,9	65,0
250	N/A	N/A	N/A	N/A	33,1	33,1	56,9	59,1
500	N/A	N/A	N/A	N/A	N/A	27,9	52,4	53,6
600	N/A	N/A	N/A	N/A	N/A	N/A	51,2	52,1
1 000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	47,9

Page 42

6.4.4.2 Pair-to-pair NEXT

Replace, on page 43, the existing Tables 8 and 9, by the following new Tables 8 and 9:

Table 8 – PS NEXT for channel

Class	Frequency MHz	Minimum PS NEXT [a] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{62,3-15\lg(f)}{-20}} + 2\times 10^{\frac{80-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}} + 2\times 10^{\frac{90-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}} + 2\times 10^{\frac{90-20\lg(f)}{-20}}\right)$ [b, d]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{99,4-15\lg(f)}{-20}} + 2\times 10^{\frac{99,4-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}} + 2\times 10^{\frac{113,3-20\lg(f)}{-20}}\right)$ [c, d]

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

[b] Whenever the Class E_A channel insertion loss at 450 MHz is less than 12 dB, subtract the term 1,4((f - 450)/50) from the equation stated above for the range of 450 MHz to 500 MHz.

[c] Whenever the Class F_A channel insertion loss at 900 MHz is less than 17 dB, subtract the term 2,8((f - 900)/100) from the equation stated above for the range of 900 MHz to 1 000 MHz.

[d] The terms in the equations are not intended to imply component performance.

Table 9 – Informative PS NEXT values for channel at key frequencies

Frequency MHz	**Minimum PS NEXT** dB				
	Class D	**Class E**	**Class E_A**	**Class F**	**Class F_A**
1	60,3	62,0	62,0	62,0	62,0
16	40,6	50,6	50,6	62,0	62,0
100	27,1	37,1	37,1	59,9	62,0
250	N/A	30,2	30,2	53,9	56,1
500	N/A	N/A	24,8	49,4	50,6
600	N/A	N/A	N/A	48,2	49,1
1 000	N/A	N/A	N/A	N/A	44,9

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6.4.5 Attenuation to crosstalk ratio (ACR)

Replace the title and the entire existing text and tables 10 and 11 of subclause 6.4.5 as follows:

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

6.4.5.1 General

ACR-N requirements are applicable to Classes D, E, E_A, F and F_A only.

In prior editions of this standard, the term *ACR* was used. Except for the name, the definition and equations for *ACR-N* are identical to those used for *ACR* in prior editions of this standard.

6.4.5.2 Pair-to-pair ACR-N

Pair-to-pair *ACR-N* is the difference between the pair-to-pair *NEXT* and the insertion loss (*IL*) of the disturbed pair in dB.

The *ACR-N* of each pair combination of a channel shall meet the difference of the *NEXT* requirement of Table 6 and the insertion loss (*IL*) requirement of Table 4 of the respective class.

The *ACR-N* requirements shall be met at both ends of the cabling.

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

$$ACR\text{-}N_{ik} = NEXT_{ik} - IL_k \quad (2)$$

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 pair k.

Table 10 – Informative ACR-N values for channel at key frequencies

Frequency MHz	Minimum ACR-N dB				
	Class D	Class E	Class E_A	Class F	Class F_A
1	59,3	61,0	61,0	61,0	61,0
16	34,5	44,9	45,0	56,9	57,0
100	6,1	18,2	19,0	42,1	44,7
250	N/A	−2,8	−0,8	23,1	26,7
500	N/A	N/A	−21,4	3,1	6,9
600	N/A	N/A	N/A	-3,4	0,7
1 000	N/A	N/A	N/A	N/A	−19,6

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

The *PS ACR-N* of each pair of a channel shall meet the difference of the *PS NEXT* requirement of Table 8 and the insertion loss (*IL*) requirement of Table 4 of the respective class. The *PS ACR-N* requirements shall be met at both ends of the cabling.

PS ACR-N$_k$ of pair *k* is computed as follows:

$$PS\ ACR\text{-}N_k = PS\ NEXT_k - IL_k \quad (3)$$

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*.

Table 11 – Informative PS ACR-N values for channel at key frequencies

Frequency MHz	Minimum PS ACR-N dB				
	Class D	Class E	Class E_A	Class F	Class F_A
1	56,3	58,0	58,0	58,0	58,0
16	31,5	42,3	42,4	53,9	54,0
100	3,1	15,4	16,2	39,1	41,7
250	N/A	−5,8	−3,7	20,1	23,7
500	N/A	N/A	−24,5	0,1	3,9
600	N/A	N/A	N/A	−6,4	−2,3
1 000	N/A	N/A	N/A	N/A	−22,6

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6.4.6 ELFEXT

Replace the title and the entire existing text and tables 12, 13, 14 and 15 of this subclause as follows:

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

6.4.6.1 General

ACR-F requirements are applicable to Classes D, E, E_A, F and F_A only.

NOTE *ACR-F* and *PS ACR-F* replace parameters *ELFEXT* and *PS ELFEXT* respectively, which were specified in prior editions of this standard. Whereas *ELFEXT* is computed using the insertion loss of the disturbing pair, *ACR-F* is computed using the insertion loss of the disturbed pair. Because both disturbing pairs and disturbed pairs are subject to the same insertion loss requirements (see Table 4), the specified requirements in Table 12 and Table 14 for Classes D, E and F have not been changed.

6.4.6.2 Pair-to-pair ACR-F

The *ACR-F* of each pair combination of a channel shall meet the requirements derived by the equations in Table 12.

$ACR\text{-}F_{ik}$ of pairs *i* and *k* is computed as follows:

$$ACR\text{-}F_{ik} = FEXT_{ik} - IL_k \tag{4}$$

where

- i is the number of the disturbing pair;
- k is the number of the disturbed pair;
- $FEXT_{ik}$ is the far-end crosstalk loss coupled from pair *i* into pair *k;*
- IL_k is the insertion loss of pair *k*.

Table 12 – ACR-F for channel

Class	Frequency MHz	Minimum ACR-F [a, b] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{63{,}8-20\lg(f)}{-20}}+4\times 10^{\frac{75{,}1-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{67{,}8-20\lg(f)}{-20}}+4\times 10^{\frac{83{,}1-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{67{,}8-20\lg(f)}{-20}}+4\times 10^{\frac{83{,}1-20\lg(f)}{-20}}\right)$
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{94-20\lg(f)}{-20}}+4\times 10^{\frac{90-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{95{,}3-20\lg(f)}{-20}}+4\times 10^{\frac{103{,}9-20\lg(f)}{-20}}\right)$

[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 shall revert to a minimum requirement of 65,0 dB.

Table 13 – Informative ACR-F values for channel at key frequencies

Frequency MHz	Minimum ACR-F dB				
	Class D	Class E	Class E_A	Class F	Class F_A
1	57,4	63,3	63,3	65,0	65,0
16	33,3	39,2	39,2	57,5	63,3
100	17,4	23,3	23,3	44,4	47,4
250	N/A	15,3	15,3	37,8	39,4
500	N/A	N/A	9,3	32,6	33,4
600	N/A	N/A	N/A	31,3	31,8
1 000	N/A	N/A	N/A	N/A	27,4

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

The *PS ACR-F* of each pair of a channel shall meet the requirements derived by the equation in Table 14.

PS ACR-F$_k$ of pair k is computed as follows:

$$PS\,ACR\text{-}F_k = \left(-10\lg \sum_{i=1,\, i\ne k}^{n} 10^{\frac{-FEXT_{ik}}{10}}\right) - IL_k \qquad (5)$$

where

- i is the number of the disturbing pair;
- k is the number of the disturbed pair;
- n is the number of disturbing pairs in the channel;
- $FEXT_{ik}$ is the far-end crosstalk loss coupled from pair i into pair k;
- IL_k is the insertion loss of pair k.

Table 14 – PS ACR-F for channel

Class	**Frequency** MHz	**Minimum PS ACR-F** [a, b] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{60{,}8-20\lg(f)}{-20}} + 4\times 10^{\frac{72{,}1-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{64{,}8-20\lg(f)}{-20}} + 4\times 10^{\frac{80{,}1-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{64{,}8-20\lg(f)}{-20}} + 4\times 10^{\frac{80{,}1-20\lg(f)}{-20}}\right)$
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{91-20\lg(f)}{-20}} + 4\times 10^{\frac{87-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{92{,}3-20\lg(f)}{-20}} + 4\times 10^{\frac{100{,}9-20\lg(f)}{-20}}\right)$

[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 shall revert to a minimum requirement of 62,0 dB.

Table 15 – Informative PS ACR-F values for channel at key frequencies

Frequency MHz	**Minimum PS ACR-F** dB				
	Class D	**Class E**	**Class E_A**	**Class F**	**Class F_A**
1	54,4	60,3	60,3	62,0	62,0
16	30,3	36,2	36,2	54,5	60,3
100	14,4	20,3	20,3	41,4	44,4
250	N/A	12,3	12,3	34,8	36,4
500	N/A	N/A	6,3	29,6	30,4
600	N/A	N/A	N/A	28,3	28,8
1 000	N/A	N/A	N/A	N/A	24,4

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6.4.7 Direct current (d.c.) loop resistance

Replace the existing Table 16 by the following new table:

Table 16 – Direct current (d.c.) loop resistance for channel

Maximum d.c. loop resistance Ω			
Class A	**Class B**	**Class C**	**Class D, E, E_A, F, F_A**
560	170	40	25

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6.4.8 Direct current (d.c.) resistance unbalance

Replace the existing text by the following new text:

For all cabling classes, the d.c. resistance unbalance between the two conductors within each pair of a channel shall not exceed 3 % or 0,200 Ω, whichever is greater. This requirement shall be achieved by design. The maximum d.c. resistance unbalance between pairs within a channel is f.f.s.

6.4.10 Operating voltage

Replace the existing title and text of this subclause as follows:

6.4.10 Dielectric withstand

Dielectric withstand of Classes D, E, E_A, F and F_A channels shall be a minimum of 1 000 V d.c. conductor-to-conductor and shall be a minimum of 1 000 V d.c. conductor-to-screen or conductor to earth, if a screen is not present. This requirement shall be met by design.

6.4.11 Power capacity

Replace the existing text of this subclause by the word void.

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6.4.12 Propagation delay

Replace the the existing tables 17 and 18 by the new tables 17 and 18 as follows:

Table 17 – Propagation delay for channel

Class	Frequency MHz	Maximum propagation delay µs
A	$f = 0,1$	20,000
B	$0,1 \le f \le 1$	5,000
C, D, E, E_A, F, F_A	$1 \le f \le$ NOTE	$0,534 + 0,036/\sqrt{f} + 4 \times 0,0025$
NOTE The equation for propagation delay applies to the upper frequency of the class.		

Table 18 – Informative propagation delay values for channel at key frequencies

Frequency MHz	**Maximum propagation delay** µs							
	Class A	**Class B**	**Class C**	**Class D**	**Class E**	**Class E_A**	**Class F**	**Class F_A**
0,1	20,000	5,000	N/A	N/A	N/A	N/A	N/A	N/A
1	N/A	5,000	0,580	0,580	0,580	0,580	0,580	0,580
16	N/A	N/A	0,553	0,553	0,553	0,553	0,553	0,553
100	N/A	N/A	N/A	0,548	0,548	0,548	0,548	0,548
250	N/A	N/A	N/A	N/A	0,546	0,546	0,546	0,546
500	N/A	N/A	N/A	N/A	N/A	0,546	0,546	0,546
600	N/A	N/A	N/A	N/A	N/A	N/A	0,545	0,545
1 000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,545

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6.4.13 Delay skew

Replace the the existing table 19 by the following new table 19:

Table 19 – Delay skew for channel

Class	**Frequency** MHz	**Maximum delay skew** µs
A	f = 0,1	N/A
B	0,1 ≤ f ≤ 1	N/A
C	1 ≤ f ≤ 16	0,050 [a]
D	1 ≤ f ≤ 100	0,050 [a, c]
E	1 ≤ f ≤ 250	0,050 [a, c]
E_A	1 ≤ f ≤ 500	0,050 [a, c]
F	1 ≤ f ≤ 600	0,030 [b, c]
F_A	1 ≤ f ≤ 1 000	0,030 [b, c]

[a] This is the result of the calculation 0,045 + 4 × 0,001 25.

[b] This is the result of the calculation 0,025 + 4 × 0,001 25.

[c] Delay skew of any given installed cabling channel shall not vary by more than 0,010 µs within this requirement, due to effects such as the daily temperature variation.

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6.4.14 Unbalance attenuation

Replace the title, the entire existing text and table 20 of this subclause as follows:

6.4.14 Unbalance attenuation and coupling attenuation

6.4.14.1 General

This standard specifies unbalance attenuation (TCL and ELTCTL) for unscreened systems and coupling attenuation for screened systems. For further information on these parameters see Annex D.

6.4.14.2 Unbalance attenuation, near-end

The unbalance attenuation near-end is measured as transverse conversion loss (*TCL*). The TCL of a channel shall meet the requirements in Table 20. The TCL requirements shall be met at both ends of the cabling.

Performance requirements for TCL are applicable to Class A, B, C, D, E, E_A, F and F_A channels and shall be achieved by design and installation in accordance with manufacturer's instructions.

Table 20 – TCL for channel for unscreened systems

Class	**Frequency** MHz	**Minimum TCL** [a] dB
A	f = 0,1	30
B	f = 0,1 f = 1	45 20
C	$1 \le f \le 16$	$30 - 5\lg(f)$
D, E, E_A, F, F_A	$1 \le f \le 30$ $30 \le f \le$ NOTE [b]	$53 - 15\lg(f)$ $60{,}3 - 20\lg(f)$

NOTE This equation for TCL applies to upper frequency of the class.

[a] *TCL* at frequencies that correspond to calculated values of greater than 40,0 dB shall revert to a minimum requirement of 40,0 dB.

[b] TCL at frequencies above 250 MHz are for information only.

It is possible to assess TCL by laboratory measurements of representative samples of channels assembled using their component and connector termination practices.

6.4.14.3 Unbalance attenuation, far-end

The unbalance attenuation far-end is measured as equal level transverse conversion transfer loss (ELTCTL). The ELTCTL of a channel shall meet the requirements as indicated in Table 21. The ELTCTL requirements shall be met at both ends of the cabling.

Performance requirements for ELTCTL are applicable to Class D, E, E_A, F and F_A channels and shall be achieved by design and installation in accordance with manufacturer's instructions.

Table 21 – ELTCTL for channel for unscreened systems

Class	**Frequency** MHz	**Minimum ELTCTL** dB
D, E, E_A, F, F_A	$1 \le f \le 30$	$30 - 20\lg(f)$

It is possible to assess ELTCTL by laboratory measurements of representative samples of channels assembled using their component and connector termination practices.

6.4.14.4 Coupling attenuation

The coupling attenuation of a channel shall meet the requirements in Table 22 at both ends.

Performance requirements for coupling attenuation are applicable to Class D, E, E_A, F and F_A systems and shall be achieved by design and installation in accordance with manufacturer's instructions.

Table 22 – Coupling attenuation for channel for screened systems

Class	**Frequency** MHz	**Minimum Coupling Attenuation** [a] dB
D, E, E_A, F, F_A	$30 \le f \le$ NOTE	$80 - 20\lg(f)$
NOTE Coupling attenuation is measured to 1 000 MHz but the limit applies to the upper frequency of the class under test.		
[a] Calculated values of greater than 40 dB shall revert to a minimum requirement of 40 dB.		

It is possible to assess coupling attenuation by laboratory measurements of representative samples of channels assembled using their component and connector termination practices.

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6.4.15 Coupling attenuation

Replace the title and the entire existing text as follows:

6.4.15 Alien crosstalk

6.4.15.1 General

The following alien crosstalk requirements are applicable only to Classes E_A and F_A. Alien crosstalk of Class F is considered to be as good as the alien crosstalk performance specified for Class E_A. For information on alien crosstalk performance of Class E systems, see ISO/IEC TR 24750.

If coupling attenuation for Class E_A or F channels is 10 dB better than Table 22 or for Class F_A channels is 25 dB better than Table 22, then the requirements of 6.4.15 are met by design.

6.4.15.2 Power sum alien NEXT (PS ANEXT)

The *PS ANEXT* of each pair of a channel shall meet the requirements derived by the equation in Table 23.

The *PS ANEXT* requirements shall be met at both ends of the channel.

$PS\ ANEXT_k$ of pair k is computed as follows:

$$PS\ ANEXT_k = -10\lg\left[\sum_{l=1}^{N}\sum_{i=1}^{n}10^{\frac{-ANEXT_{l,i,k}}{10}}\right] \tag{6}$$

where

k	is the number of the disturbed pair in the disturbed channel;
i	is the number of the disturbing pair in a disturbing channel l;
l	is the number of the disturbing channel;
N	is the number of disturbing channels;
n	is the number of disturbing pairs in disturbing channel l;
$ANEXT_{l,i,k}$	is the alien near-end crosstalk loss coupled from pair i of disturbing channel (l) to the pair k of the disturbed channel.

Table 23 – PS ANEXT for channel

Class	**Frequency** MHz	**Minimum PS ANEXT** [a] dB
E_A [b, c]	$1 \le f < 100$	$80 - 10\lg(f)$
	$100 \le f \le 500$	$90 - 15\lg(f)$
F_A	$1 \le f < 100$	$95 - 10\lg(f)$
	$100 \le f \le 1\,000$	$105 - 15\lg(f)$

[a] *PS ANEXT* at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[b] If the average insertion loss of all disturbed pairs at 100 MHz, $IL_{100\text{MHz,avg}}$, is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

$$\text{minimum}\left\{7\cdot\frac{f-100}{400}\cdot\frac{7-IL_{100\text{MHz,avg}}}{IL_{100\text{MHz,avg}}},\ 6\cdot\frac{f-100}{400}\right\}$$

where

f is the frequency in MHz;

$$IL_{100\text{MHz,avg}} = \frac{1}{4}\sum_{i=1}^{4} IL_{100\text{MHz},i};$$

$IL_{100\text{MHz},i}$ is the insertion loss of a pair i at 100 MHz.

[c] If coupling attenuation is at least 10 dB better than the requirements in Table 22, the calculation in [b] is not required.

Table 24 – Informative PS ANEXT values for channel at key frequencies

Frequency MHz	**Minimum PS ANEXT** dB	
	Class E_A	**Class F_A**
1	67,0	67,0
100	60,0	67,0
250	54,0	67,0
500	49,5	64,5
1 000	N/A	60,0

6.4.15.3 PS $ANEXT_{avg}$

The $PS\ ANEXT_{avg}$ of a channel shall meet the requirements derived by the equations in Table 25.

The $PS\ ANEXT_{avg}$ requirements shall be met at both ends of the channel.

$PS\ ANEXT_{avg}$ is computed as follows:

$$PS\ ANEXT_{avg} = \frac{1}{n}\left[\sum_{k=1}^{n} PS\ ANEXT_k\right] \tag{7}$$

where

k is the number of the disturbed pair in the disturbed channel;

n is the number of disturbed pairs in the disturbed channel;

$PS\ ANEXT_k$ is the power sum alien near-end crosstalk loss coupled to pair k of the disturbed channel.

Table 25 – PS ANEXT$_{avg}$ for channel

Class	Frequency MHz	Minimum PS ANEXT$_{avg}$ [a, b, c, d] dB
E_A	$1 \le f < 100$	$82,25 - 10\lg(f)$
	$100 \le f \le 500$	$92,25 - 15\lg(f)$

[a] *PS ANEXT*$_{avg}$ at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[b] If the average insertion loss of all disturbed pairs at 100 MHz, $IL_{100MHz,avg}$, is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

$$\text{minimum}\left\{7 \cdot \frac{f-100}{400} \cdot \frac{7 - IL_{100MHz,avg}}{IL_{100MHz,avg}},\ 6 \cdot \frac{f-100}{400}\right\}$$

where

f is the frequency in MHz;

$$IL_{100MHz,avg} = \frac{1}{4}\sum_{i=1}^{4} IL_{100MHz,i};$$

$IL_{100MHz,i}$ is the insertion loss of a pair i at 100 MHz.

[c] If coupling attenuation is at least 10 dB better than the requirements in Table 22, the calculation in Footnote b is not required.

[d] *PS ANEXT*$_{avg}$ for Class F_A channels is met if the Class F_A PS ANEXT requirements in Table 23 are met.

Table 26 – Informative PS ANEXT$_{avg}$ values for channel at key frequencies

Frequency MHz	Minimum Class E_A PS ANEXT$_{avg}$ dB
1	67,0
100	62,3
250	56,3
500	51,8

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

The *PS AACR-F* of each pair of a channel shall meet the requirements in Table 27.

The *PS AACR-F* shall be met at both ends of the channel.

The *PS AACR-F* is computed based on *AFEXT*, and insertion losses of disturbing and disturbed channels.

6.4.15.5 PS AFEXT for Class E_A channels

The *PS AFEXT* for Class E_A is computed as follows:

If coupling attenuation is at least 10 dB better than the requirements in Table 22, then the *PS AFEXT* is determined by equation (13).

The measured pair-to-pair alien FEXT values of a wire pair *k* in a disturbed channel from the disturbing channel *l* are normalized by the difference of the insertion losses of disturbing and disturbed channels

$AFEXT_{norm}$ is computed from Equations 8 to 11 as follows

If

$$IL_k - IL_{l,i} > 0 \tag{8}$$

then

$$AFEXT_{\text{norm}\,l,i,k} = AFEXT_{l,i,k} - IL_{l,i} + IL_k - 10\lg\left(\frac{IL_k}{IL_{l,i}}\right) \tag{9}$$

If

$$IL_k - IL_{l,i} \le 0 \tag{10}$$

then

$$AFEXT_{\text{norm}\,l,i,k} = AFEXT_{l,i,k} \tag{11}$$

where

- *k* is the number of the disturbed pair in the disturbed channel;
- *i* is the number of the disturbing pair in a disturbing channel *l*;
- *l* is the number of the disturbing channel;
- $AFEXT_{l,i,k}$ is the alien far-end crosstalk loss coupled from pair *i* of disturbing channel (*l*) to the pair *k* of the disturbed channel;
- IL_k is the measured insertion loss of pair *k* in the disturbed channel;
- $IL_{l,i}$ is the measured insertion loss of pair *i* of disturbing channel *l*.

The *PS AFEXT* is determined according to Equation 12.

$$PS\,AFEXT_k = -10\lg\left(\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{\frac{-\left(AFEXT_{\text{norm}\,l,i,k}\right)}{10}}\right) \tag{12}$$

where

- *N* is the number of disturbing channels;
- *n* is the number of disturbing pairs in disturbing channel *l*;
- *k* is the number of the disturbed pair in the disturbed channel;
- *i* is the number of the disturbing pair in a disturbing channel *l*;