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TRANSMISSION PERFORMANCE SPECIFICATIONS
FOR
4-PAIR 100 Ω AUGMENTED CATEGORY 6 CABLING

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

FOREWORD

(This foreword is not part of the Standard)

In 2003, the Telecommunications Industry Association (TIA) developed objectives for augmented category 6 cabling intended to support 10 Gigabit applications over a distance of 100 meters. At the request of the Institute of Electrical and Electronics Engineers (IEEE) 802.3 Committee, TIA agreed to specify augmented category 6 cabling systems and components to 500 MHz in order to support 10GBASE-T. The project was assigned to TR-42.7 under Engineering Committee TR-42. The TR-42.7 Sub-Committee cooperated with several groups related to this activity.

(Note: Stuart plans to submit alternate wording)

a) TR-42.1 – Commercial Building Telecommunications Cabling Sub-Committee

b) TR-42.7.1 – Copper Connectors Working Group

c) TR-42.7.2 – Copper Cable Working Group

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This standard has been prepared by the TR-42.7 Subcommittee and approved by the Engineering Committee TR-42.

There are XXX annexes in this Standard. Annexes YYY are normative and considered a mandatory part of this Standard. Annexes ZZZ are informative and not considered a part of this Standard.

1 INTRODUCTION

2 PURPOSE AND SCOPE

To develop cabling and component specifications and test procedures to support the operation of IEEE 802.3 10GBASE-T over 100 meters of structured balanced twisted-pair copper cabling. This addendum includes extending the frequency range and adding requirements to those specified in TIA-568-B.2-1.

3 NORMATIVE REFERENCES

The following standards contain requirements that, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision; parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated. ANSI and TIA maintain registers of currently valid national standards published by them.

Note to editor: Review the reference list before the first ballot.

ANSI/ICEA S-80-576, *Communications Wire and Cable for Wiring Premises*, 1994

ANSI/ICEA S-90-661, *Individually Unshielded Twisted Pair Indoor Cable for Use in Communication Wiring Systems*, 1994

ANSI/TIA/EIA-568-B.1, *Commercial Building Telecommunications Standard Part 1: General Requirements*, 2001

ANSI/TIA/EIA-568-B.2, *Commercial Building Telecommunications Standard Part 2: Balanced Twisted-pair* Cabling *Components*, 2001

ANSI/TIA/EIA-568-B.2-1, *Commercial Building Telecommunications Standard Part 2:* Addendum 1: Transmission Performance Specifications for 4-Pair 100 Ohm category 6 cabling

ANSI/TIA/EIA-568-B.2-3, *Additional Considerations for Insertion Loss and Return Loss Pass/Fail Determination*, 2002

ANSI/TIA/EIA-568-B.3, *Commercial Building Telecommunications Standard Part 3: Optical Fiber Cabling Components*, 2000

ASTM D 4566-98, *Standard Test Methods for Electrical Performance Properties of Insulations and Jackets for Telecommunications Wire and Cable*, 1998

IEC 60603-7, *Connectors for frequencies below 3 MHz for use with printed boards – Part 7: Detail specification for connectors, 8-way, including fixed and free connectors with common mating features, with assessed quality*, 1996

4 DEFINITIONS, ACRONYMS & ABBREVIATIONS

4.1 Definitions

The generic definitions in this section have been formulated for use by the entire family of telecommunications infrastructure standards. As such, the definitions do not contain mandatory requirements of the Standard. Specific requirements are found in the normative sections of this Standard.

Alien crosstalk : A measure of the unwanted signal coupling from a transmitter into a neighboring pair that is external to the transmitter's cabling channel or part thereof.

Alien near-end crosstalk (ANEXT) loss: A measure of the unwanted signal coupling from a transmitter at the near end into a neighboring pair that is external to the transmitter's cabling channel or part thereof, measured at the near end.

Power sum alien near-end crosstalk (PSANEXT) loss: A computation of the unwanted signal coupling from multiple transmitters at the near end into a neighboring pair that is external to the transmitters' cabling channels or part thereof, measured at the near end.

Alien far-end crosstalk (AFEXT) loss: A measure of the unwanted signal coupling from a transmitter at the near end into a neighboring pair that is external to the transmitter's cabling channel or part thereof, measured at the far end

Power sum alien far-end crosstalk (PSAFEXT) loss: A computation of the unwanted signal coupling from multiple transmitters at the near end into a neighboring pair that is external to the transmitters' cabling channels or part thereof, measured at the far end.

4.2 Acronyms and abbreviations

ANEXT Alien Near End Crosstalk

PSANEXT Power Sum Alien Near End Crosstalk

AFEXT Alien Far End Crosstalk

PSAFEXT Power Sum Alien Far End Crosstalk

5 TEST CONFIGURATIONS

5.1 Component test configurations

Cable test configurations
Connecting hardware test configurations
Modular cord test configurations

Editor's Note: Trent Hayes to provide cable configurations for this clause. Masood Shariff to position appropriately within the document. Consider the difference between modeling and test configurations.

Editor's Note: Sterling Vaden to provide connecting hardware configurations for this clause. Masood Shariff to position appropriately within the document. Consider the difference between modeling and test configurations.

Editor's Note: Masood to add pointers to cable and connecting hardware ANEXT measurement methods in the correct annexes.

5.2 Cabling test configurations

Channel test configurations
Permanent link test configurations

Editor's Note: Shadi AbuGhazaleh to provide configurations for this clause. Masood Shariff to position appropriately within the document. Consider the difference between modeling and test configurations.

(Note: Minimum channel and permanent link configurations are needed. For example, see annex O of TIA/EIA-568-B.2.)

6 COMPONENTS

6.1 Recognized cable

The following category of twisted-pair cable is recognized in addition to those identified in clause 4.2.1 of ANSI/TIA/EIA-568-B.2:

> Augmented Category 6: This designation applies to 100 Ω cables whose transmission characteristics are specified up to 500 MHz.

6.1.1 Horizontal cable

Four-pair 100 Ω UTP and ScTP cables are recognized for use in augmented category 6 horizontal cabling systems. The cable shall consist of 22 AWG to 24 AWG thermoplastic insulated solid conductors that are formed into four individually twisted pairs and enclosed by a thermoplastic jacket. The cable shall meet all of the mechanical requirements of ANSI/ICEA S-80-576 applicable to four-pair inside wiring cable for plenum or general cabling within a building. In addition to the applicable requirements of ANSI/ICEA S-90-661-1994, the physical design of horizontal cables shall meet the requirements of clauses 4.3.3.1 to 4.3.3.6 of ANSI/TIA/EIA-568-B.2.

> NOTE – Additional requirements for 100 Ω ScTP cables are located in annex K of ANSI/TIA/EIA-568-B.2.

6.1.2 Cable for modular cords

No text available. This is covered in section 7 as different IL and RL requirements for stranded cable.

6.1.3 Backbone cable

Four-pair 100 Ω UTP and ScTP cables are recognized for use in augmented category 6 backbone cabling systems. The cable shall consist of 22 AWG to 24 AWG thermoplastic insulated solid conductors that are formed into four individually twisted-pairs and enclosed by a thermoplastic jacket. The cable shall meet all of the mechanical requirements of ANSI/ICEA S-80-576 applicable to four-pair inside wiring cable for plenum or general cabling within a building. In addition to the applicable requirements of ANSI/ICEA S-90-661-1994, the physical design of backbone cables shall meet the requirements of clauses 4.4.3.1 to 4.4.3.6 of ANSI/TIA/EIA-568-B.2.

NOTE – Additional requirements for 100 Ω ScTP cables are located in annex K of ANSI/TIA/EIA-568-B.2.

6.1.4 Bundled and hybrid cable

add, “The alien crosstalk of bundled and hybrid cable shall meet the requirements of this specification.”

Bundled and hybrid cables may be used for horizontal and backbone cabling provided that each cable type is recognized (see clause 6.1.1 of this Standard and clause 4.4 of ANSI/TIA/EIA-568-B.1) and meets the transmission and color-code specifications for that cable type as given in ANSI/TIA/EIA-568-B.2, ANSI/TIA/EIA-568-B.3, and clause 7 of this Standard. Additionally, for all frequencies from 1 MHz to 500 MHz, the total power sum NEXT loss for any disturbed pair from all pairs external to that pair’s jacket within the bundled or hybrid cable shall not exceed the values determined using equation (1). Calculated power sum NEXT loss limit values that exceed 65 dB shall revert to a limit of 65 dB.

$$PSNEXT_{bundled\_and\_htbrid,all\_pairs} \geq X - 15\log(f/100) \quad \textbf{(TBD)} \tag{1}$$

> NOTES,
>
> 1 Hybrid UTP cables (color coded per ANSI/TIA/EIA-568-B.2, clause 4.3.3.3) can be

distinguished from multipair UTP backbone cables (color coded per ANSI/TIA/EIA-568-B.2, clause 4.4.3.3) by the color coding scheme and by the transmission requirements.

2 Hybrid cables consisting of optical fiber and copper conductors are sometimes referred to as composite cables.

The individual cables within a bundled cable shall meet the applicable requirements in clause 4 of ANSI/TIA/EIA-568-B.3, clause 4 of ANSI/TIA/EIA-568-B.2, annex K of ANSI/TIA/EIA-568-B.2, annex M of ANSI/TIA/EIA-568-B.2, and clause 7 of this Standard after bundle formation.

6.2 Recognized connecting hardware

The following category of twisted-pair connecting hardware is recognized in addition to those identified in clause 5.4.1 of ANSI/TIA/EIA-568-B.2:

Augmented Category 6: This designation applies to 100 Ω connecting hardware whose transmission characteristics are specified from 1 MHz to 500 MHz.

6.3 Cords

Patch cords, equipment cords, and work area cords used for system moves, adds, and changes are critical to transmission performance. Augmented category 6 cords and cordage shall meet the applicable requirements of clauses 6.1 through 6.3 of ANSI/TIA/EIA-568-B.2 and clause 7 of this standard.

7 TRANSMISSION REQUIREMENTS

7.1 Insertion loss

1

7.1.1 Cable insertion loss

Table 2 - Augmented category 6 cable insertion loss @ 20 °C ± 3°C (68° F ± 5.5 °F)

7.1.2 Connecting hardware insertion loss

Table 3 – Augmented category 6 connecting hardware insertion loss

7.1.3 Cabling insertion loss

For all frequencies from 1 MHz to 500 MHz, when measured according to the procedures in annex C of TIA-568-B.2-1, the channel insertion loss shall meet the values determined using equation YY. For the purposes of field measurements, calculated channel limits that result in insertion loss values less than 3 dB revert to a requirement of 3 dB maximum (see ANSI/TIA/EIA-568-B.2-3). Insertion loss values in Table 4 computed from equation YY are provided for information only at certain frequencies of interest.

$$IL_{channel} \leq 1.05 * (1.8 * \sqrt{f} + 0.01f + 0.2/\sqrt{f} + 4 * 0.02 * \sqrt{f}) \qquad \text{(YY)}$$

It is understood that equation YY includes an ILD allowance.

Table 4 – Augmented category 6 channel insertion loss

Frequency (MHz)	Insertion Loss (dB)
1.00	2.2
4.00	4.1
8.00	5.7
10.00	6.4
16.00	8.1
20.00	9.1
25.00	10.2
31.25	11.4
62.50	16.3
100.00	20.8
200.00	30.0
250.00	33.8
300.00	37.4
400.00	43.7
500.00	49.4

NOTES,

1 A 20 % increase in insertion loss is allowed over category 6 horizontal cable insertion loss for work area and patch cords as shown in equation (TBD).

2 The insertion loss of the channel does not take into consideration the 0.1 dB measurement floor of the connecting hardware insertion loss requirement.

3 The channel insertion loss requirement is derived using the insertion loss contribution of 4 connections.

4 For the purposes of field measurements, calculated channel limits that result in insertion loss values less than 3 dB revert to a requirement of 3 dB maximum (see ANSI/TIA/EIA-568-B.2-3).

(Permanent link insertion loss requirements are to be added.)

Editor's Note: Need a contribution approved by the task group to implement any technical changes.

Table 5– Augmented category 6 permanent link insertion loss

7.2 NEXT loss

NEXT loss is a measure of the unwanted signal coupling from a transmitter at the near-end into neighboring pairs measured at the near-end. NEXT loss is expressed in dB relative to the transmit signal level. NEXT loss shall be measured for all pair combinations of cables and cabling in accordance with annex C of ANSI/TIA/EIA-568-B.2 and the ASTM D 4566 NEXT loss measurement procedure, except the test fixture shall provide for consistent common and differential mode impedance matching for the unjacketed twisted-pairs between the cable jacket and the balun terminations. Connecting hardware NEXT loss shall be measured for all pair combinations in accordance with annex E. Modular plug cord NEXT loss shall be measured for all pair combinations in accordance with annex J. In addition, since each duplex channel can be disturbed by more than one duplex channel, power sum near-end crosstalk (PSNEXT) loss is also specified for cabling and cables.

7.2.1 Pair-to-pair NEXT loss

7.2.1.1 Cable pair-to-pair NEXT loss

Table 6 - Augmented category 6 cable NEXT loss @ 20 °C ± 3 °C (68 °F ± 5.5° F), worst pair-to-pair

7.2.1.2 Connecting hardware pair-to-pair NEXT loss

Table 7 – Augmented category 6 connecting hardware NEXT loss, worst pair-to-pair

7.2.1.3 Work area, equipment, and patch cord pair-to-pair NEXT loss

Table 8 – Augmented category 6 modular cord NEXT loss, worst pair-to-pair

7.2.1.4 Cabling pair-to-pair NEXT loss

For all frequencies from 1 MHz to 500 MHz, augmented category 6 channel pair-to-pair NEXT loss measurements in the laboratory shall meet the values determined using table 9 while field measurements shall meet the values determined using equation XX. Calculations that result in NEXT loss values greater than 65 dB shall revert to a requirement of 65 dB minimum. The values in table 10 are provided for information only.

Table 9 – Augmented category 6 channel NEXT loss requirements, worst pair-to-pair laboratory measurements

Frequency (MHz)	NEXT Loss, worst pair-to-pair laboratory measurements (dB)
$1 \le f \le$ 330	$PSNEXT_{channel} \ge -20\log(10^{\frac{-(44.3-15\cdot\log(f/100))}{20}} + 2\cdot 10^{\frac{-(54-20\cdot\log(f/100))}{20}})$
330 < $f \le$500	31.0-27.15*log(f/330)

Equation (XX)

$$NEXT_{channel} \ge -20\log(10^{\frac{-(44.3-15\cdot\log(f/100))}{20}} + 2\cdot 10^{\frac{-(54-20\cdot\log(f/100))}{20}}) - \text{margin allowance}$$

where

margin allowance $= 3\cdot\frac{(f-330)}{170}$ $\quad 330 \le f \le 500\ MHz$

Table 10 – Augmented category 6 channel NEXT loss, worst pair-to-pair values

Frequency (MHz)	NEXT loss (dB) laboratory measurements	NEXT loss (dB) field measurements
1.00	65.0	65.0
4.00	63.0	63.0
8.00	58.2	58.2
10.00	56.6	56.6
16.00	53.2	53.2
20.00	51.6	51.6
25.00	50.0	50.0
31.25	48.4	48.4
62.50	43.4	43.4
100.00	39.9	39.9

200.00	34.8	34.8
250.00	33.1	33.1
300.00	31.7	31.7
400.00	28.7	28.3
500.00	26.1	24.9

For all frequencies from 1 MHz to 500 MHz, category 6 permanent link pair-to-pair NEXT loss shall meet the values determined using table 11. Calculations that result in NEXT loss values greater than 65 dB shall revert to a requirement of 65 dB minimum. The values in table 12 are provided for information only.

Table 11 – Augmented category 6 permanent link NEXT loss requirements, worst pair-to pair

Frequency (MHz)	**NEXT Loss, worst pair-to-pair (dB)**
$1 \le f \le 300$	$NEXT_{PL} \ge -20\log\left(10^{\frac{-(44.3-15\cdot\log(f/100))}{20}}+10^{\frac{-(54-20\cdot\log(f/100))}{20}}\right)$
$300 < f \le 500$	34 - 33.13*log(f/300)

Table 12 – Augmented category 6 permanent link NEXT loss, worst pair-to pair values

Frequency (MHz)	**NEXT loss (dB)**
1.00	73.4
4.00	64.1
8.00	59.4
10.00	57.8
16.00	54.6
20.00	53.1
25.00	51.5
31.25	50.0
62.50	45.1
100.00	41.8
200.00	36.9
250.00	35.3
300.00	34.0
400.00	29.9
500.00	26.7

7.2.2 Power sum NEXT loss

Power sum near-end crosstalk loss takes into account the combined crosstalk (statistical) on a receive pair from all near-end disturbers operating simultaneously. The power sum near-end crosstalk (PSNEXT) loss is calculated in accordance with ASTM D 4566 as a power sum on a selected pair from all other pairs as shown in equation (22) for the case of 4-pair cable.

$$PSNEXT = -10\log\left(10^{-X1/10} + 10^{-X2/10} + 10^{-X3/10}\right)\ dB \qquad (22)$$

where:

X1, X2, X3 are the pair-to-pair crosstalk measurements in dB between the selected pair and the other three pairs.

NOTE - For channel and permanent link power sum calculations, it is assumed that the pair-to-pair connecting hardware NEXT loss requirements of this Standard are equivalent to a PSNEXT loss performance of 50-20log(*f*/100) for all frequencies from 1 MHz to 500 MHz. PSNEXT loss for connecting hardware does not need to be separately verified.

7.2.2.1 Cable power sum NEXT loss

7.2.2.2 Cabling power sum NEXT loss

For all frequencies from 1 MHz to 500 MHz, augmented category 6 channel power sum NEXT loss loss measurements in the laboratory shall meet the values determined using table 13 while field measurements shall meet the values determined using equation YY. Calculations that result in NEXT loss values greater than 62 dB shall revert to a requirement of 62 dB minimum. The values in table 14 are provided for information only.

Table 13 – Augmented category 6 channel power sum NEXT loss requirements

Frequency (MHz)	Power Sum NEXT Loss (dB)
$1 \le f \le 330$	$PSNEXT_{channel} \ge -20\log\left(10^{\frac{-(42.3-15\cdot\log(f/100))}{20}} + 2\cdot 10^{\frac{-(50-20\cdot\log(f/100))}{20}}\right)$
$330 < f \le 500$	28-26.43*log(f/330)

Equation YY

$$PSNEXT_{channel} \ge -20\log\left(10^{\frac{-(42.3-15\cdot\log(f/100))}{20}} + 2\cdot 10^{\frac{-(50-20\cdot\log(f/100))}{20}}\right) - \text{margin allowance}$$

where

margin allowance $= 3\cdot\frac{(f-330)}{170}$ $\qquad 330 \le f \le 500\ MHz$

Table 14 – Augmented category 6 channel PSNEXT loss values @ 20 °C ± 3 °C (68 °F ± 5.5 °F)

Frequency (MHz)	PSNEXT (dB) laboratory measurements	PSNEXT (dB) field measurements
1.00	62.0	62.0
4.00	60.5	60.5
8.00	55.6	55.6
10.00	54.0	54.0
16.00	50.6	50.6
20.00	49.0	49.0
25.00	47.3	47.3
31.25	45.7	45.7
62.50	40.6	40.6
100.00	37.1	37.1
200.00	31.9	31.9
250.00	30.2	30.2

300.00	28.8	28.8
400.00	25.8	25.3
500.00	23.2	21.8

For all frequencies from 1 MHz to 500 MHz, augmented category 6 permanent link power sum NEXT loss shall meet the values determined using table 15. Calculations that result in NEXT loss values greater than 62 dB shall revert to a requirement of 62 dB minimum. The values in table 16 are provided for information only.

Table 15 – Augmented category 6 permanent link PSNEXT loss requirements

Frequency (MHz)	PSNEXT Loss (dB)
$1 \le f \le 300$	$PSNEXT_{PL} \ge -20\log(10^{\frac{-(42.3-15\cdot\log(f/100))}{20}} + 10^{\frac{-(50-20\cdot\log(f/100))}{20}})$
$300 < f \le 500$	31.4-34.44*log(f/300)

Table 16 – Augmented category 6 permanent link PSNEXT loss values

Frequency (MHz)	PSNEXT (dB)
1.00	62.0
4.00	61.8
8.00	57.0
10.00	55.5
16.00	52.2
20.00	50.7
25.00	49.1
31.25	47.5
62.50	42.7
100.00	39.3
200.00	34.3
250.00	32.7
300.00	31.4
400.00	27.1
500.00	23.8

7.3 ELFEXT and FEXT loss

FEXT loss is a measure of the unwanted signal coupling from a transmitter at the far-end into neighboring pairs measured at the near-end. FEXT loss is the ratio of the power coupled from a disturbing pair into the disturbed pair relative to the input power at the opposite end of the transmission lines determined from measured voltages. This ratio is expressed in dB. ELFEXT shall be calculated for all pair combinations of cables and cabling in accordance with annex C of ANSI/TIA/EIA-568-B.2 and the ASTM D 4566 FEXT loss measurement procedure, except the test fixture shall provide for consistent common and differential mode impedance matching for the unjacketed twisted-pairs between the cable jacket and the balun terminations. Connecting hardware FEXT loss shall be measured for all pair combinations in accordance with annex E of TIA-568-B.2-1. In addition, since each duplex channel can be disturbed by more than one duplex channel, power sum equal level far-end crosstalk (PSELFEXT) is also specified for cabling and cables.

7.3.1 Pair-to-pair ELFEXT

FEXT loss is a measure of the unwanted signal coupling from a transmitter at the far-end into neighboring pairs measured at the near-end. FEXT loss is the ratio of the power coupled from a disturbing pair into the disturbed pair relative to the input power at the opposite end of the transmission lines determined from measured voltages. This ratio is expressed in dB. ELFEXT shall be calculated for all pair combinations of cables and cabling in accordance with annex C of ANSI/TIA/EIA-568-B.2 and the ASTM D 4566 FEXT loss measurement procedure, except the test fixture shall provide for consistent common and differential mode impedance matching for the unjacketed twisted-pairs between the cable jacket and the balun terminations. Connecting hardware FEXT loss shall be measured for all pair combinations in accordance with annex E. In addition, since each duplex channel can be disturbed by more than one duplex channel, power sum equal level far-end crosstalk (PSELFEXT) is also specified for cabling and cables.

7.3.1.1 Cable pair-to-pair ELFEXT

For all frequencies from 1 MHz to 500 MHz, augmented category 6 cable ELFEXT, for a length of 100 m (328 ft), shall meet the values determined using equation (26). The values in table 17 are provided for information only.

$$ELFEXT_{cable} \geq 27.8 - 20\log(f/100) \text{ dB} \qquad (26)$$

Table 17 - Augmented category 6 cable ELFEXT @ 20 °C ± 3 °C (68 °F ± 5.5 °F), worst pair-to-pair

7.3.1.2 Connecting hardware pair-to-pair FEXT loss

For all frequencies from 1 MHz to 500 MHz, category 6 connecting hardware FEXT loss shall meet the values determined using equation (27). Calculations that result in FEXT loss values greater than 75 dB shall revert to a requirement of 75 dB minimum. The values in table 18 are provided for information only.

$$FEXT_{conn} \geq 43.1 - 20\log(f/100)\ dB \quad \textbf{\{TBD\}} \tag{27}$$

Table 18 – Augmented category 6 connecting hardware FEXT loss, worst pair-to-pair

7.3.1.3 Cabling pair-to-pair ELFEXT

For all frequencies from 1 MHz to 500 MHz the channel ELFEXT shall meet the values determined using the equation XX. Due to measurement considerations, ELFEXT values that correspond to measured FEXT values of greater than 70 dB are for information only. ELFEXT values in Table 16 computed from the equation XX are provided for information only at certain frequencies of interest.

$$ELFEXT_{channel} \geq -20\log(10^{\frac{-ELFEXT_{cable}}{20}} + 4 \cdot 10^{\frac{-FEXT_{conn}}{20}})\ dB \tag{XX}$$

Table 19 – Augmented category 6 channel ELFEXT, worst pair-to-pair

Frequency (MHz)	ELFEXT (dB)
1.00	63.3
4.00	51.2
8.00	45.2
10.00	43.3
16.00	39.2
20.00	37.2
25.00	35.3
31.25	33.4
62.50	27.3
100.00	23.3
200.00	17.2
250.00	15.30
300.00	13.7
400.00	11.2
500.00	9.3

For all frequencies from 1 MHz to 500 MHz, augmented category 6 permanent link ELFEXT shall meet the values determined using table 20. The values in table 21 are provided for information only.

Table 20 – Augmented category 6 permanent link ELFEXT, worst pair-to-pair requirements

Frequency (MHz)	ELFEXT worst pair-to-pair (dB)
$1 \le f \le 500$	**{TBD}** $ELFEXT_{PL} \ge -20\log(10^{\frac{-(27.8-20\cdot\log(f/100))}{20}} + 3*10^{\frac{-(43.1-20\cdot\log(f/100))}{20}})$

Table 21 – Augmented category 6 permanent link ELFEXT, worst pair-to-pair values

7.3.2 Power sum ELFEXT

Power sum equal level far-end crosstalk loss takes into account the combined crosstalk (statistical) on a receive pair from all far-end disturbers operating simultaneously. The power sum equal level far-end crosstalk (PSELFEXT) loss is calculated in accordance with ASTM D 4566 as a power sum on a selected pair from all other pairs as shown in equation (30) for the case of 4-pair cable.

$$PSELFEXT = -10\log(10^{-X1/10} + 10^{-X2/10} + 10^{-X3/10})\ dB \tag{30}$$

where:

X1, X2, X3 are the pair-to-pair crosstalk measurements in dB between the selected pair and the other three pairs.

NOTE - For channel and permanent link power sum calculations, it is assumed that the pair-to-pair connecting hardware FEXT loss requirements of this Standard are equivalent to a PSFEXT loss performance of 40.1-20log(*f*/100) **{TBD}** for all frequencies from 1 MHz to 500 MHz **{TBD}**. PSFEXT loss for connecting hardware does not need to be separately verified.

7.3.2.1 Cable power sum ELFEXT

For all frequencies from 1 MHz to 500 MHz, augmented category 6 cable power sum ELFEXT, for a length of 100 m (328 ft), shall meet the values determined by equation (31). The values in table 22 are for reference only.

$$PSELFEXT_{cable} \ge 24.8 - 20\log(f/100)\ dB \tag{31}$$

Table 22 - Augmented category 6 cable power sum ELFEXT @ 20 °C ± 3 °C (68 °F ± 5.5 °F)

7.3.2.2 Cabling power sum ELFEXT

For all frequencies from 1 MHz to 500 MHz the channel PSELFEXT shall meet the values determined using the equation ZZ. Due to measurement considerations, PSELFEXT values that correspond to measured FEXT values of greater than 70 dB are for information only. PSELFEXT values in Table 19 computed from the equation ZZ are provided for information only at certain frequencies of interest.

$$PSELFEXT_{channel} \geq -20\log(10^{\frac{-PSELFEXT_{cable}}{20}} + 4 \cdot 10^{\frac{-PSFEXT_{conn}}{20}})\ dB \qquad \text{(ZZ)}$$

Table 23 – Augmented category 6 channel power sum ELFEXT

Frequency (MHz)	PSELFEXT (dB)
1.00	60.3
4.00	48.2
8.00	42.2
10.00	40.3
16.00	36.2
20.00	34.2
25.00	32.30
31.25	30.4
62.50	24.3
100.00	20.3
200.00	14.2
250.00	12.30
300.00	10.7
400.00	8.2
500.00	6.3

For all frequencies from 1 MHz to 500 MHz, augmented category 6 permanent link power sum ELFEXT shall meet the values determined using table 24. The values in table 25 are provided for information only.

Table 24 – Augmented category 6 permanent link power sum ELFEXT requirements

Frequency (MHz)	Power Sum ELFEXT (dB)
$1 \leq f \leq 500$	**{TBD}** $PSELFEXT_{PL} \geq -20\log(10^{\frac{-(24.8-20\cdot\log(f/100))}{20}} + 3*10^{\frac{-(40.1-20\cdot\log(f/100))}{20}})$

Table 25 – Augmented category 6 permanent link power sum ELFEXT values

7.4 Return loss

Return loss is a measure of the reflected energy caused by impedance mismatches in the cabling system and is especially important for applications that use simultaneous bi-directional transmission. Return loss is the ratio of the reflected signal power to the input power determined from measured voltages, expressed in dB. Cable and cabling return loss shall be measured in accordance with annex C of ANSI/TIA/EIA-568-B.2. Connecting hardware return loss shall be measured in accordance with annex D of ANSI/TIA/EIA-568-B.2 for all pairs. Modular plug cords shall be measured in accordance with annex J for all pairs.

7.4.1 Horizontal cable return loss

For all frequencies from 1 MHz to 500 MHz, augmented category 6 horizontal cable return loss, for a length of 100 m (328 ft), shall meet the values determined using the equations specified in table 26. The values in table 27 are provided for information only.

Table 26 - Augmented category 6 horizontal cable return loss requirements @ 20°C ± 3°C (68° F ± 5.5° F)
For a length of 100 m (328 ft)

Frequency (MHz)	Return Loss (dB)
$1 \le f < 10$	$20+5\log(f)$
$10 \le f < 20$	25
$20 \le f < 500$	$25-7\log(f/20)$

Table 27 - Augmented category 6 solid conductor cable return loss values @ 20 °C ± 3 °C (68 °F ± 5.5 °F)
For a length of 100 m (328 ft)

Frequency (MHz)	Return Loss (dB)
1.0	20.0
4.0	23.0
8.0	24.5
10.0	25.0
16.0	25.0
20.0	25.0
25.0	24.3
31.25	23.6
62.5	21.5
100.0	20.1
200.0	18.0
250.0	17.3
300.0	16.8
400.0	15.9
500.0	15.2

7.4.2 Stranded conductor cable return loss

For all frequencies from 1 MHz to 500 MHz, augmented category 6 stranded patch cable return loss, for a length of 100 m (328 ft), shall meet the values determined using the equations specified in table 28. The values in table 29 are provided for information only.

Table 28 - Augmented category 6 stranded conductor cable return loss requirements @ 20 °C ± 3 °C (68 °F ± 5.5 °F)
For a length of 100 m (328 ft)

Frequency (MHz)	Return Loss (dB)
$1 \le f < 10$	$20+5\log(f)$
$10 \le f < 20$	25
$20 \le f < 500$	$25-8.6\log(f/20)$

Table 29 - Augmented category 6 stranded conductor cable return loss values @ 20 °C ± 3 °C (68 °F ± 5.5 °F)
Values For a length of 100 m (328 ft)

Frequency (MHz)	Return Loss (dB)
1.0	20.0
4.0	23.0
8.0	24.5
10.0	25.0
16.0	25.0
20.0	25.0
25.0	24.2
31.25	23.3
62.5	20.7
100.0	19.0
200.0	16.4
250.0	15.6
300.0	14.9
400.0	13.8
500.0	13.0

7.4.3 Connecting hardware return loss

Table 30 – Augmented category 6 connecting hardware return loss requirements

Frequency (MHz)	Return Loss (dB)
$1 \le f < 79$ **{TBD}** **{TBD}** $79 \le f < 500$	30 $28-20\log(f/100)$ **{TBD}**

For the purpose of establishing PL and Channel RL limits, a connection value of 26 – 20log(f/100) (TBD) is assumed to account for the variability of patch cord connections.

7.4.4 Work area, equipment, and patch cord return loss

Table 31 - Augmented category 6 work area, equipment, and patch cord return loss

7.4.5 Cabling return loss

For all frequencies from 1 MHz to 500 MHz, augmented category 6 channel return loss shall meet or exceed the values determined using the equations specified in table 32 up to 500 MHz. The values in table 33 are provided for information only.

Table 32 – Augmented Category 6 channel return loss requirements

Frequency (MHz)	Return Loss (dB)
$1 \le f < 10$ $10 \le f < 40$ $40 \le f < 500$	19 $24-5\log(f)$ $32-10\log(f)$ 6 dB minimum

Table 33 – Augmented category 6 channel return loss values

Frequency (MHz)	Return Loss (dB)
1.0	19.0
4.0	19.0
8.0	19.0
10.0	19.0
16.0	18.0
20.0	17.5
25.0	17.0
31.25	16.5
62.5	14.0
100.0	12.0
200.0	9.0
250.0	8.0
300.0	7.2
400.0	6.0
500.0	6.0

For all frequencies from 1 MHz to 250 MHz, augmented category 6 permanent link return loss shall meet the values determined using the equations specified in table 34. The values in table 35 are provided for information only

Table 34 – Augmented category 6 permanent link return loss requirements

Frequency (MHz)	Return Loss (dB)
$1 \leq f < 3$	$21+4\log(f/3)$
$3 \leq f < 10$	21
$10 \leq f < 40$	$26-5\log(f)$
$40 \leq f <= 250$	$34-10\log(f)$
$250 \leq f \leq 500$	10-20log(f/250) {TBD} 6 dB minimum {TBD}

Table 35 – Augmented category 6 permanent link return loss values

Frequency (MHz)	Return Loss (dB)
1.0	19.1
4.0	21.0
8.0	21.0
10.0	21.0
16.0	20.0
20.0	19.5
25.0	19.0
31.25	18.5
62.5	16.0
100.0	14.0
200.0	11.0
250.0	10.0
300.0	8.4
400.0	6.0
500.0	6.0

7.5 Propagation delay/delay skew

7.5.1 Cable propagation delay

Table 36 - Propagation delay and delay skew for augmented category 6 cable @ 20 °C ± 3 °C (68 °F ± 5.5 °F)

7.5.2 Cabling propagation delay

In determining the augmented category 6 channel and permanent link propagation delay, the propagation delay contribution of each installed mated connection is assumed to not exceed 2.5 ns from 1 MHz to 500 MHz.

The maximum propagation delay for an augmented category 6 channel configuration shall be less than 555 ns measured at 10 MHz.

The maximum propagation delay for an augmented category 6 permanent link configuration shall be less than 498 ns measured at 10 MHz.

7.5.3 Cable propagation delay skew

7.5.3 Cabling propagation delay skew

In determining the channel and permanent link propagation delay skew, the propagation delay skew of each installed mated connection is assumed not to exceed 1.25 ns.

The maximum propagation delay skew for an augmented category 6 channel configuration shall be less than 50 ns measured at 10 MHz.

The maximum propagation delay skew for an augmented category 6 permanent link configuration shall be less than 44 ns measured at 10 MHz.

7.6 Balance

7.6.1 Transverse conversion loss (TCL)

7.6.1.1 Cable TCL

Table 37 – Augmented category 6 cable TCL

7.6.1.2 Connecting hardware TCL

Table 38 – Augmented category 6 connecting hardware TCL

7.6.2 Equal Level transverse conversion transfer loss (ELTCTL)

7.6.2.1 Cable ELTCTL

Table 39 – Augmented category 6 cable ELTCTL

7.6.2.2 Connecting hardware TCTL

Table 40 – Augmented category 6 connecting hardware TCTL

7.7 Alien NEXT

Alien NEXT is the coupling of cross-talk noise at the near end from external cabling pairs into a victim pair of the 4-pair cabling under test. Power sum alien NEXT is the calculated power sum of the alien NEXT from all external cabling pairs into the victim pair. Cable alien NEXT and alien ELFFEXT shall be measured according to Annex A.

7.7.1 Channel power sum alien NEXT

For all frequencies from 1 MHz to 500 MHz, when measured according to the procedures in Annex XX, the channel power sum alien NEXT shall meet or exceed the values determined using the equations in Table 36. Calculations that result in PSANEXT values greater than 75 dB TBD shall revert to a requirement of 75 dB TBD minimum. Power sum alien NEXT values in Table 41 computed from the equations in Table 42 are provided for information only at certain frequencies of interest.

Table 41 – Augmented category 6 channel power sum alien NEXT requirements

Frequency f (MHz)	PSANEXT (dB)
1 MHz >= f =< 100 MHz	$60 - 10 * Log_{10} (f/100)$
100 MHz < f =< 500 MHz	$60 - 15 * Log_{10} (f/100)$

Table 42 – Augmented category 6 channel PSANEXT @ 20 °C ± 3 °C (68 °F ± 5.5 °F)

Frequency (MHz)	PSANEXT (dB)
1.0	75.0
4.0	74.0
8.0	71.0
10.0	70.0
16.0	68.0
20.0	67.0
25.0	66.0
31.25	65.1
62.5	62.0
100.0	60.0
200.0	55.5
250.0	54.0
300.0	52.8
400.0	51.0
500.0	49.5

7.7.2 Channel power sum alien ELFEXT

For all frequencies from 1 MHz to 500 MHz, when measured according to the procedures in Annex XX, the channel power sum alien ELFEXT shall meet or exceed the values determined using the equations ZZ. Calculations that result in PSAELFEXT values greater than 75 dB TBD shall revert to a requirement of 75 dB TBD minimum. Power sum alien ELFEXT values in Table 43 computed from the equation ZZ are provided for information only at certain frequencies of interest.

Alien PSAELFEXT cable >/= X-20*Log(f/100) (ZZ)

Where: X = TBD dB

Table 43 – Augmented category 6 channel PSAELFEXT @ 20 °C ± 3 °C (68 °F ± 5.5 °F)

Frequency (MHz)	PSAELFEXT (dB)

1.0	
4.0	
8.0	
10.0	
16.0	
20.0	
25.0	
31.25	
62.5	
100.0	
200.0	
250.0	
300.0	
400.0	
500.0	

ANNEX A Cable ANEXT and AFEXT reference test procedure (normative)

A.1 Purpose

To measure alien near end crosstalk, ANEXT, between pairs of adjacent cables in a 7 cable assembly. The frequency range is 1-500 MHz.

A.2 Equipment

Network Analyzer
Baluns
100 Ohm pair terminations
Tie wraps or other cable binding devices
Seven 100 meter lengths of 4 pair UTP cable

A.3 Procedure

Prepare the cables to be tested in the form of an assembly consisting of seven cables utilizing tie wraps longitudinally spaced about 8 inches apart. The seven cables shall be maintained in a six-around-one parallel configuration throughout the length to be tested as shown in figure A-1 (to be quickly drawn up by Shadi “Picasso” AbuGhazaleh). The 6 cables shall not be deformed by the tie wraps. The assembly shall be laid out on the floor of the test facility in one large loop or serpentine configuration so that crossovers do not occur. The pairs at each end of the assembly shall be prepared for termination with common and differential resistors. The far end of the pairs under test and both ends of the remaining pairs shall be terminated.

Measure the NEXT loss and FEXT between all pairs of the middle victim cable and each pair of all adjacent cables.

For modeling channel performance, cable PSANEXT loss and PSAFEXT values shall be determined from the assumptions in annex C.

Editor’s note: Move “of the same design” somewhere in the body of the Standard where the PSANEXT loss and PSAFEXT test method is called out.

A.4 Results

Calculate PSANEXT and PSAFEXT from the measured data.

Editor’s Note: Add figures shown in contribution #189/#190 to this text.

ANNEX B Connecting hardware ANEXT and AFEXT reference test procedure (normative)

Editor's Note: The annex headers need to be formatted correctly. This text is expected to be provided by the connecting hardware ANEXT task group by The February meeting.

ANNEX C Channel ANEXT and AFEXT test configurations (normative) (TBD)

Editor's Note: The annex headers and clauses need to be formatted correctly (Val can help).

C.1 Reference measurement instructions

1. Pull seven to ten (depending on conduit fill) up to 90 meter 4-Pair cables into a conduit with a length of > 30 meters. The conduit shall be sized to ensure a conduit fill of 40 % ± 3.5 %. The conduit fill is calculated as the ratio of $N^*(D_{cable})^2 / (D_{conduit})^2$ expressed as a percentage. See table below for standard EMT conduit sizes and the number of cables within the fill range specified above.

N Cables	DIA (in)	3/4 0.824 % Fill	1 1.047 % Fill	1 1/4 1.38 % Fill
9	0.17	38.3%		
8	0.18	38.2%		
7	0.19	37.2%		
7	0.2	41.2%		
10	0.21		40.2%	
9	0.22		39.7%	
8	0.23		38.6%	
7	0.24		36.8%	
7	0.25		39.9%	
7	0.26		43.2%	
10	0.27			38.3%
9	0.28			37.1%
9	0.29			39.7%
8	0.3			37.8%
8	0.31			40.4%

2. Pull-out a maximum of 1 meter of cable for attachment to the measurement equipment.
   •Measure NEXT and FEXT between all of the 4-pair cable pair combinations excluding within cable pair combinations.
   •Calculate Power Sum NEXT and ELFEXT

3. Pull-out 5 meters of the 90 meter 4-Pair cables from the conduit and tie-wrap every meter
   •Measure NEXT and FEXT between all of the 4-pair cable pair combinations excluding within cable pair combinations.
   •Calculate Power Sum NEXT and ELFEXT

4. Terminate cable pairs to adjacent Category compatible connecting hardware patch panel positions. Use a 1 meter test cord.
   •Measure NEXT and FEXT between all of the 4-pair cabling pair combinations excluding within cable pair combinations.
   •Calculate Power Sum NEXT and ELFEXT

C.2 Additional ANEXT measurement procedures being discussed

- 2 cables in a conduit
- 2 cables bound together
- 6 around 1 cables bound together
- drum accumulator with a spiral groove for 2 cables
- two cables side by side with fixed spacing
- connecting hardware ANEXT measurement procedures
- channel ANEXT and AELFEXT measurement procedures