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ADDITIONAL GUIDELINES FOR 4-PAIR 100 Ω CATEGORY 6 CABLING FOR 10GBASE-T APPLICATIONS

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FOREWORD

(This foreword is not part of the Telecommunications Systems Bulletin)

At the request of the Institute of Electrical and Electronics Engineers (IEEE) 802.3 Working Group, TIA agreed to create additional guidelines for 4-pair 100 Ω Category 6 Cabling for 10GBASE-T Applications. The project was assigned to TR-42.7 under Engineering Committee TR-42.

TIA standards documents are developed within the Technical Committees of the TIA and the standards coordinating committees of the TIA standards board. Members of the committees serve voluntarily and without commission. The companies that they represent are not necessarily members of the TIA. The standards developed within the TIA represent a consensus of the broad expertise on the subject. This expertise comes from within the TIA as well as those outside of the TIA that have an expressed interest. The viewpoint expressed at the time that this standard was approved was from the contributors' experience and the state of the art at that time. Users are encouraged to verify that they have the latest revision of the standard.

This telecommunications bulletin has been prepared by the TR-42.7 Subcommittee and approved by the Technical Committee TR-42.

There are four annexes in this TSB. Annexes A, B, C, and D..

1 INTRODUCTION

The guidelines of this Telecommunications Systems Bulletin contain additional recommendations for a minimally compliant category 6 cabling system. These recommendations are intended to further characterize the existing category 6 cabling plant for 10GBASE-T applications.

This Telecommunications Systems Bulletin includes field test procedures that can be used to verify if the installed cabling will meet these new guidelines.

NOTE - The terms "guidelines" and "recommendations" are used interchangeably within this Telecommunications Systems Bulletin.

2 PURPOSE AND SCOPE

This Telecommunications Systems Bulletin describes additional guidelines for 100 Ω, 4-pair category 6 cabling that have been installed in accordance with TIA/EIA-568-B.2.-1 to support the proposed IEEE 802.3an 10GBASE-T standard. These guidelines are intended to provide additional information on the extended frequency transmission performance of category 6 cabling from 250 MHz up to 500 MHz. It also characterizes the crosstalk coupling between adjacent 4-pair category 6 cabling channels referred to as alien crosstalk and provides additional guidelines for field test equipment and field test methods and alien crosstalk mitigation in support of 10GBASE-T. The transmission recommendations included herein are intended to provide a means to assess installations of category 6 cabling as specified in TIA/EIA-568-B.-1 and corresponding addenda up to the extended frequencies and additional parameters needed for 10GBASE-T support. The TSB does not place any normative requirements for existing category 6 installations.

3 REFERENCES

The following standards are referenced in this text. At the time of publication, the editions indicated were valid. All standards are subject to revision; parties to agreements based on this TSB 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.

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

ANSI/TIA/EIA-568-B.2, *Commercial Building Telecommunications Standard Part 2: 100 Ohm Balanced Twisted-pair Cabling Standard*

ANSI/TIA/EIA-568-B.2-1, Transmission Performance Specifications for 4 Pair 100 Ohm Category 6 Cabling

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 between adjacent cabling or components (forward to Definitions Group).

Alien near-end crosstalk loss: A measure of the unwanted signal coupling between pairs in adjacent cabling from transmitters at the near-end into a pair measured at the near-end (forward to Definitions Group).

Power sum alien near-end crosstalk loss: A computation of the unwanted signal coupling between pairs in adjacent cabling from multiple transmitters at the near-end into a pair measured at the near-end (forward to Definitions Group).

Alien far-end crosstalk(ffs): A measure of the unwanted signal coupling between pairs in adjacent cabling from a transmitter at the near-end into a pair measured at the far-end (forward to Definitions Group).

Power sum Alien far-end crosstalk(ffs): A computation of the unwanted signal coupling between pairs in adjacent cabling from multiple transmitters at the near-end into another pair measured at the far-end. (forward to Definitions Group).

Power sum alien equal level far-end crosstalk(ffs): A computation of the unwanted signal coupling between pairs in adjacent cabling from multiple transmitters at the near-end into another pair measured at the far-end, and relative to the received signal level (forward to Definitions Group).

4.2 Acronyms and abbreviations

ANEXT	Alien Near-end Crosstalk (forward to Definitions Group)
PSANEXT	Power sum near-end crosstalk (forward to Definitions Group)
AFEXT (ffs)	Alien Far-end Crosstalk (forward to Definitions Group)
PSAFEXT (ffs)	Power sum near-end crosstalk (forward to Definitions Group)
PSAELFEXT (ffs)	Power sum alien equal level crosstalk (forward to Definitions Group)

5 TEST CONFIGURATIONS

5.1 Cabling channel and permanent link test configurations

Assessment of the channel and permanent link transmission parameters over the frequency range of 1 MHz to 500 MHz is recommended (see Annex A.).

The channel test configuration is used by system designers and users of data communications systems to verify the performance of the overall channel. The channel includes up to 90 m (295 ft) of horizontal cable, a work area equipment cord, a telecommunications outlet/connector, an optional transition/consolidation connector, and two connections in the telecommunications room. The total length of equipment cords, patch cords or jumpers and work area cords does not exceed 10 m (33 ft). The channel configuration excludes the connections to the equipment at each end of the channel. The channel definition does not apply to those cases where the horizontal cabling is cross-connected to the backbone cabling. A schematic representation of the channel test configuration is illustrated in figure 1.

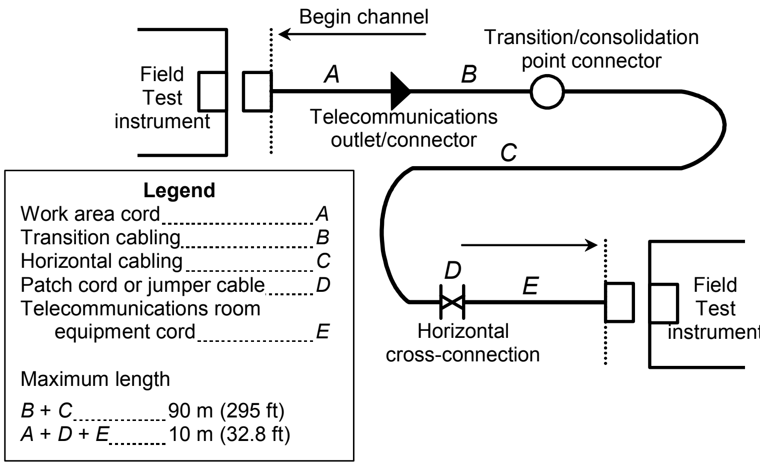

Figure 1 Schematic representation of a channel test configuration

The permanent link test configuration is used by installers and users of data telecommunications systems to verify the performance of permanently installed cabling. The permanent link consists of up to 90 m (295 ft) of horizontal cabling and one connection at each end and may also include an optional transition/consolidation point connection. The permanent link configuration excludes both the cable portion of the field tester cord and the connection to the field test device. A schematic representation of the permanent link test configuration is illustrated in figure 2.

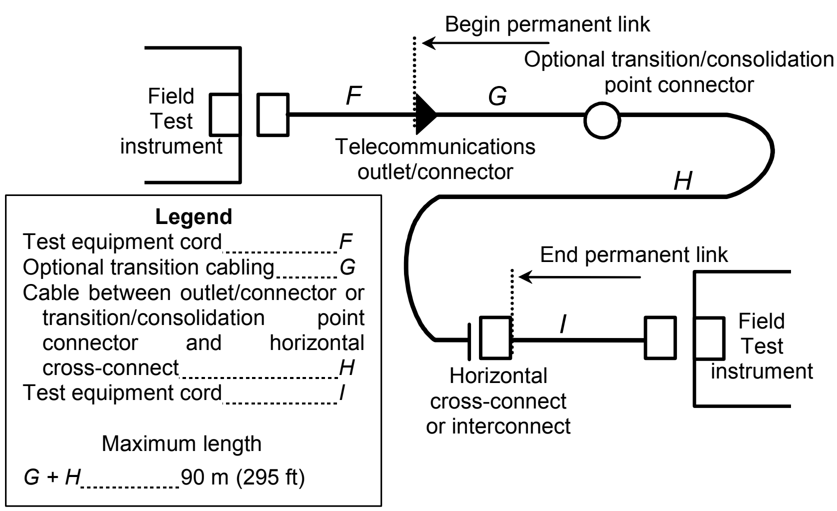

Figure 2 Schematic representation of a permanent link test configuration

5.2 Alien Crosstalk test configurations

The Alien Crosstalk test configurations are used by system designers and users of data communications systems to verify the alien crosstalk performance between the disturbed pair and disturbing pairs of category 6 channels and permanent links. The transmission performance of the channel and permanent link test configurations consists of single channels and permanent links and therefore does not address the alien crosstalk test configurations. 10GBASE-T is designed to operate over at least 55 meters of Category 6 cabling within a "reasonable" worst case alien crosstalk environment as described in the alien crosstalk test configurations provided in Annex D.

Alien crosstalk field testing procedures and alien crosstalk mitigation guidelines are addressed in Annex A and Annex C. respectively.

6 TRANSMISSION PARAMETERS

6.1 Insertion Loss

Insertion loss is a measure of the signal loss resulting from the insertion of cabling or a component between a transmitter and receiver. It is often referred to as attenuation. Insertion loss is the ratio of signal power at the receiver end to the input power determined from measured voltages, expressed in dB.

6.1.1 Cabling insertion loss

6.1.1.1 Channel Insertion Loss

For all frequencies from 1 MHz to 250 MHz, the category 6 channel insertion loss meets the values determined using equation (1) as specified in TIA/EIA-568-B.2.-1.

$$INSERTIONLOSSchannel \le 1.924 \times \sqrt{f} + 0.0173 \times f + \frac{0.204}{\sqrt{f}} + 0.0003 \times f^{1.5} \quad \text{dB} \qquad (1)$$

For all frequencies (250 < f ≤ 500) the insertion loss of the channel should meet the values determined using equation (2).

$$INSERTIONLOSSchannel \le 1.05\left(1.82 \times \sqrt{f} + 0.0169 \times f + \frac{0.25}{\sqrt{f}}\right) + 4 \times 0.02 \times \sqrt{f} \quad \text{dB} \quad (2)$$

6.1.1.2 Permanent Link Insertion Loss

For all frequencies from 1 MHz to 250 MHz, the category 6 permanent link meets the values determined using equation (3) as specified in TIA/EIA-568-B.2.-1. For all frequencies (250 < f ≤ 500) the insertion loss of the permanent link should meet the values determined using equation (3).

(TBD) dB (3)

6.1.3 Insertion Loss Scaling

To ensure reliable 10GBASE-T operation, a minimum signal to noise ratio (SNR) is necessary. The PS ANEXT loss guideline of 6.4.2 can be relaxed based on a reduction in the maximum insertion loss specified in 6.1.1. The insertion loss reduction can be achieved by scaling the length of the cabling insertion loss.

The scaled Category 6 channel insertion loss is defined by equation (4):

$$Scaled\_IL\_channel \le \frac{Length\_m}{100} \times 1.05\left(1.82 \times \sqrt{f} + 0.0169 \times f + \frac{0.25}{\sqrt{f}}\right) + 4 \times 0.02 \times \sqrt{f} \quad \text{dB} \qquad (4)$$

6.1.4 Insertion Loss of a Category 6 channel of 55 meters

For all frequencies from 1 MHz to 250 MHz, the category 6 insertion loss of a 55 meter channel meets the values determined using equation (5). For all frequencies (250 < f ≤ 500) MHz the category 6 insertion loss of a 55 meter channel should meet the values determined using equation (5).

$$Scaled\_IL\_channel(55\ m) \le \frac{55}{100} \times 1.05 \left(1.82 \times \sqrt{f} + 0.0169 \times f + \frac{0.25}{\sqrt{f}}\right) + 4 \times 0.02 \times \sqrt{f} \quad \text{dB} \qquad (5)$$

6.1.5 Insertion Loss of a Category 6 permanent link of (TBD meters)

For all frequencies from 1 MHz to 250 MHz, the category 6 insertion loss of a (TBD) meter permanent link meets the values determined using equation (6). For all frequencies (250 < f ≤ 500) MHz the category 6 insertion loss of a 55 meter channel should meet the values determined using equation (6).

(TBD) dB

(6)

6.2 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. In addition, since each duplex channel can be disturbed by more than one duplex channel, power sum near-end crosstalk (PSNEXT) loss is also provided.

6.2.1 Cabling Pair-to-pair NEXT loss

6.2.1.1 Pair-to-pair NEXT Loss Channel

For all frequencies from 1 MHz to 250 MHz, the category 6 channel pair-to-pair NEXT loss meets the values determined using equation (7) as specified in TIA/EIA-568-B.2.-1.

$$NEXTchannel \ge -20 \times log10\left(10^{\frac{44.3-15\ log10\left(\frac{f}{100}\right)}{-20}} + 2 \times 10^{\frac{54-20\ log10\left(\frac{f}{100}\right)}{-20}}\right) \text{dB} \qquad (7)$$

For all frequencies between (250 < f < 330) MHz the channel pair-to-pair NEXT loss should meet the values determined using equation (7).

For all frequencies (330 ≤ f ≤ 500) MHz the channel pair-to-pair NEXT loss of the cabling should meet the values determined using equation (8).

$$NEXTchannel \ge 31 - 50 \times log10\left(\frac{f}{330}\right) \text{dB} \qquad (8)$$

6.2.1.2 Pair-to-pair NEXT Loss Permanent Link

For all frequencies from 1 MHz to 250 MHz, the category 6 permanent pair-to-pair NEXT loss meets the values determined using equation (9) as specified in TIA/EIA-568-B.2.-1.

$$NEXTpermanent\_link \ge -20 \times log10\left(10^{\frac{44.3-15\ log10\left(\frac{f}{100}\right)}{-20}} + 10^{\frac{54-20\ log10\left(\frac{f}{100}\right)}{-20}}\right) \text{dB} \qquad (9)$$

For all frequencies between (250 < f < 300) MHz the permanent pair-to-pair NEXT loss should meet the values determined using equation (9)-TBD.

For all frequencies (300 ≤ f ≤ 500) MHz the permanent pair-to-pair NEXT loss of the cabling should meet the values determined using equation (10)-TBD.

$$NEXTpermanent\_link \geq 34 - 48 \times log10\left(\frac{f}{300}\right) \text{ dB(TBD)} \qquad \textbf{(10)}$$

6.2.2 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 D4566 as a power sum on a selected pair from all other pairs as shown in equation (10) for the case of 4-pair cable.

$$PSNEXT = -10\log(10^{-X1/10} + 10^{-X2/10} + 10^{-X3/10}) \ dB \qquad (11)$$

where:

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

6.2.2.1 Cabling power sum NEXT loss

6.2.2.1.1 PSNEXT Loss Channel

For all frequencies from 1 MHz to 250 MHz, the category 6 channel power sum NEXT loss meets the values determined using equation (12) as specified in TIA/EIA-568-B.2.-1.

$$PSNEXTchannel \geq -20 \times log10\left(10^{\frac{42.3-15\,log10\left(\frac{f}{100}\right)}{-20}} + 2 \times 10^{\frac{50-20\,log10\left(\frac{f}{100}\right)}{-20}}\right) dB \qquad (12)$$

For all frequencies (250 < f < 330) MHz the channel power sum NEXT loss should meet the values determined using equation (11).

For all frequencies (330 ≤ f ≤ 500) MHz the channel power sum NEXT loss of the cabling should meet the values determined using equation (12).

$$PSNEXTchannel \geq 28 - 42 \times log10\left(\frac{f}{330}\right) dB \qquad (13)$$

6.2.2.1.2 PSNEXT Loss Permanent Link

For all frequencies from 1 MHz to 250 MHz, the category 6 permanent link power sum NEXT loss meets the values determined using equation (14) as specified in TIA/EIA-568-B.2.-1.

$$PSNEXTpermanent\_link \geq -20 \times log10\left(10^{\frac{42.3-15\,log10\left(\frac{f}{100}\right)}{-20}} + 10^{\frac{50-20\,log10\left(\frac{f}{100}\right)}{-20}}\right) dB \qquad (14)$$

For all frequencies between (250 < f < 300) MHz the permanent link power sum NEXT loss should meet the values determined using equation (14)-TBD.

For all frequencies (300 ≤ f ≤ 500) MHz the permanent link power sum NEXT loss of the cabling should meet the values determined using equation (15)-TBD.

$$PSNEXTpermanent\_link \geq 31.4 - 40 \times log10\left(\frac{f}{300}\right) \text{ dB(TBD)} \qquad (15)$$

6.3 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 is expressed in dB as the difference between the measured FEXT loss and the insertion loss of the disturbed pair. 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 provided.

6.3.1 Cabling pair-to-pair ELFEXT

6.3.1.1 Pair-to-pair ELFEXT Channel

For all frequencies from 1 MHz to 250 MHz, the category 6 channel ELFEXT meets the values determined using equation (13) as specified in TIA/EIA-568-B.2.-1. For all frequencies (250 < f ≤ 500) the category 6 channel ELFEXT of the channel should meet the values determined using equation (16).

$$ELFEXTchannel \geq -20 \times log10\left(10^{\frac{27.8-20\,log10\left(\frac{f}{100}\right)}{-20}} + 4 \times 10^{\frac{43.1-20\,log10\left(\frac{f}{100}\right)}{-20}}\right) \text{ dB} \qquad (16)$$

6.3.1.2 Pair-to-pair ELFEXT Permanent Link

For all frequencies from 1 MHz to 250 MHz, the category 6 permanent link ELFEXT meets the values determined using equation (14) as specified in TIA/EIA-568-B.2.-1. For all frequencies (250 < f ≤ 500) the category 6 permanent link ELFEXT of the permanent link should meet the values determined using equation (17).

$$ELFEXTpermanent\_link \geq 20 \times log10\left(10^{\frac{27.8-20\,log10\left(\frac{f}{100}\right)}{-20}} + 3 \times 10^{\frac{43.1-20\,log10\left(\frac{f}{100}\right)}{-20}}\right) \text{ dB} \qquad (17)$$

6.3.2 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 D4566 as a power sum on a selected pair from all other pairs as shown in equation (18) for the case of 4-pair cable.

$$PSELFEXT = -10\log(10^{-X1/10} + 10^{-X2/10} + 10^{-X3/10}) \; dB \qquad (18)$$

where:

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

6.3.2.1 Cabling power sum ELFEXT

6.3.2.1.1 Power sum ELFEXT Channel

For all frequencies from 1 MHz to 250 MHz, the category 6 channel power sum ELFEXT meets the values determined using equation (16) as specified in TIA/EIA-568-B.2.-1. For all frequencies (250 < f ≤ 500) the category 6 channel power sum ELFEXT should meet the values determined using equation (19).

$$PSELFEXTchannel \geq -20 \times log10\left(10^{\frac{24.8-20\ log10\left(\frac{f}{100}\right)}{-20}} + 4 \times 10^{\frac{40.1-20\ log10\left(\frac{f}{100}\right)}{-20}}\right) \text{db} \qquad (19)$$

6.3.2.1.2 Power sum ELFEXT Permanent Link

For all frequencies from 1 MHz to 250 MHz, the category 6 permanent link power sum ELFEXT meets the values determined using equation (17) as specified in TIA/EIA-568-B.2.-1. For all frequencies (250 < f ≤ 500) the category 6 permanent link power sum ELFEXT should meet the values determined using equation (20).

$$PSELFEXTpermanent\_link \geq 20 \times log10\left(10^{\frac{24.8-20\ log10\left(\frac{f}{100}\right)}{-20}} + 3 \times 10^{\frac{40.1-20\ log10\left(\frac{f}{100}\right)}{-20}}\right) \text{dB} \qquad (20)$$

6.4 Alien NEXT loss

Alien NEXT loss is a measure of the unwanted signal coupling between pairs in adjacent cabling from transmitters at the near-end into a pair measured at the near-end. Alien NEXT loss is expressed in dB relative to the transmit signal level. In addition, since each duplex channel can be disturbed by more than one duplex channel in adjacent cabling, power sum Alien near-end crosstalk (PS ANEXT) loss is also provided.

Editors Note: Alien NEXT Measurement procedure is under study.

6.4.1 Pair-to-pair ANEXT loss (ffs)

6.4.1.1 Cabling pair-to-pair ANEXT loss

6.4.1.1.1 ANEXT Channel Equation (21)

6.4.1.1.2 ANEXT Permanent Link Equation (22)

6.4.2 Power sum Alien NEXT loss

Power sum Alien near-end crosstalk loss takes into account the combined crosstalk (statistical) on a receive pair from near-end disturbers in adjacent cables operating simultaneously. The power sum near-end crosstalk (PSANEXT) loss is determined by summing the power of the individual pair-to-pair differential Alien NEXT loss values over the frequency range 1 MHz to 500 MHz as follows in equation (21):

$$-10 \times \log 10 \sum_{i=1}^{n} 10^{\frac{-AN(f)\ i}{10}} \quad \text{(dB)} \qquad (23)$$

where

AN(f)i is the magnitude in dB of PS ANEXT loss at frequency f of pair combination i

i is the pair-to-pair combination (1 to n)
n is the number of pair-to-pair combinations between adjacent cabling

6.4.2.1 Power sum Alien NEXT loss for a Category 6 channel of 100 meters

For a 10GBASE-T 100 meter Category 6 channel with the maximum insertion loss specified in 6.1 the PS ANEXT loss between the disturbed duplex channel and the disturbing duplex channels in adjacent cabling should meet the values determined using equation (24).

$$PS\ ANEXT > \begin{cases} 62 - 10\cdot\log_{10}(f_{MHz}/100) & 1\text{ MHz} \le f \le 100\text{ MHz} \\ 62 - 15\cdot\log_{10}(f_{MHz}/100) & 100\text{ MHz} < f \le 500\text{ MHz} \end{cases} \quad (24)$$

6.4.2.2 Power sum Alien NEXT loss Adjustment

The adjusted PS ANEXT loss requirement is determined by first calculating the PS ANEXT_constant and utilizing the constant in the PS ANEXT limit line model.

The PS ANEXT_constant is defined by the following equation (25):

$$PSANEXT\_Constant = 62 - (Cat6\_IL\_250MHz - SCat6\_IL\_250MHz) \times \frac{15}{15.6}\ \text{dB} \quad (25)$$

where

Cat6_IL_250MHz is the Category 6 insertion loss at 250 MHz for a 100 meter channel
SCat6_IL_250MHz is the scaled Category 6 insertion at 250 MHz

6.4.2.3 PS ANEXT for a Category 6 channel of 55 meters

For a 10GBASE-T 55 meter Category 6 channel with the maximum insertion loss specified in 6.1.3 the PS ANEXT loss between the disturbed duplex channel and the disturbing duplex channels in adjacent cabling should meet the values determined using equation (26).

$$PS\ ANEXT > \begin{cases} 47 - 10\cdot\log_{10}(f_{MHz}/100) & 1\text{ MHz} \le f \le 100\text{ MHz} \\ 47 - 15\cdot\log_{10}(f_{MHz}/100) & 100\text{ MHz} < f \le 500\text{ MHz} \end{cases} \quad (26)$$

6.5 Alien FEXT and Alien ELFEXT loss

Alien FEXT is a measure of the unwanted signal coupling from a transmitter at the far-end into neighboring pairs measured at the near-end. Alien 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.

Alien ELFEXT is expressed in dB as the difference between the measured Alien FEXT loss and the insertion loss of the disturbed pair. In addition, since each duplex channel can be disturbed by more than one duplex channel in adjacent cabling power sum Alien near-end crosstalk (PS AELFEXT) loss is also provided.

6.5.1 Pair-to-pair AELFEXT loss (ffs)

6.5.1.1 Cabling pair-to-pair AELFEXT loss

6.5.1.1.1 AELFEXT Channel

6.5.1.1.2 AELFEXT Permanent Link

6.5.2 Power sum Alien ELFEXT loss

Power sum alien 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 alien equal level far-end crosstalk (PS AELFEXT) loss is determined by summing the power of the individual pair-to-pair differential Alien ELFEXT loss values over the frequency range 1 MHz to 500 MHz as follows in equation (27):

$$-10 \times log10 \sum_{i=1}^{n} 10^{\frac{-AEL(f)\ i}{10}} \quad \text{(dB)} \qquad (27)$$

where

AEL(f)i is the magnitude in dB of PS AELFEXT loss at frequency f of pair combination i
i is the pair-to-pair combination (1 to n)
n is the number of pair-to-pair combinations between adjacent cable

6.5.2.1 Power sum Alien ELFEXT loss for a Category 6 channel of 100 meters

For a 10GBASE-T 100 meter Category 6 channel with the maximum insertion loss specified in 6.1 the PS AELFEXT loss between the disturbed duplex channel and the disturbing duplex channels in adjacent cabling should meet the values determined using equation (28).

$$PSAELFEXT \geq 37 - 20 \times log10\left(\frac{f}{100}\right) \text{ dB} \qquad (28)$$

6.5.2.2 Power sum Alien ELFEXT Adjustment (ffs)

6.5.2.3 PS AELFEXT loss for a Category 6 channel of 55 meters

For a 10GBASE-T 55 meter Category 6 channel with the maximum insertion loss specified in 6.1.3 the PS AELFEXT loss between the disturbed duplex channel and the disturbing duplex channels in adjacent cabling should meet the values determined using equation (29).

$$PSAELFEXT \geq 33.6 - 20 \times log10\left(\frac{f}{100}\right) \text{ dB} \qquad (29)$$

6.6 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 expressed in dB relative to the reflected signal level.

6.6.1 Cabling Return Loss

6.6.1.1 Channel return loss

For all frequencies from 1 MHz to 250 MHz, the category 6 channel return loss meets the values specified in table 1 as specified in TIA/EIA-568-B.2.-1 table 29. For all frequencies (250 < f ≤ 500) the category 6 channel return loss should meet the values in Table 1.

Table 1 Category 6 channel return loss

Frequency (MHz)	Return Loss (dB)
1 ≤ f < 10	19
10 ≤ f < 40	24- 5log10(f)
40 ≤ f ≤ 250	32- 10log10(f)
250 < f < 400	32- 10log10(f)
400 ≤ f ≤ 500	6

6.6.1.2 Permanent link return loss

For all frequencies from 1 MHz to 250 MHz, the category 6 permanent link return loss meets the values specified in table 2 as specified in TIA/EIA-568-B.2.-1 table 31. For all frequencies (250 < f ≤ 500) the category 6 channel return loss should meet the values in Table 2.

Table 2 Category 6 permanent link return loss

Frequency (MHz)	Return Loss (dB)
1 ≤ f < 3	21+4log10(f/3)
3≤ f <10	21
10≤ f < 40	26-5log10(f)
40≤ f ≤250	34-10log10(f)
250<f < 400	10-20log(f/250)
400 ≤ f ≤ 500	6

6.7 Propagation delay/delay skew

Propagation delay is the time it takes for a signal to propagate from one end to the other. Propagation delay skew is a measurement of the signaling delay difference from the fastest pair to the slowest. Propagation delay and propagation delay skew are expressed in nanoseconds (ns). Propagation delay and propagation delay skew are measured for all pairs for cables in accordance with ASTM D4566. Propagation delay and propagation delay skew is measured for all pairs for cabling in accordance with annex D of ANSI/TIA/EIA-568-B.2.

6.7.1 Cabling propagation delay

The maximum propagation delay for a category 6 channel configuration is less than 555 ns measured at 10 MHz as specified in TIA/EIA-568-B.2.-1.

The maximum propagation delay for a category 6 permanent link configuration is less than 498 ns measured at 10 MHz as specified in TIA/EIA-568-B.2.-1.

6.7.2 Cabling propagation delay skew

The maximum propagation delay skew for a category 6 channel configuration is less than 50 ns as specified in TIA/EIA-568-B.2.-1.

The maximum propagation delay skew for a category 6 permanent link configuration does not exceed 44 ns as specified in TIA/EIA-568-B.2.-1.

Annex A

Annex A Cabling (field) measurement procedures

A.1 General

When performed, field test measurements should be made in accordance with annex I of ANSI/TIA/EIA-568-B.2 unless otherwise noted.

A.2 Frequency range

Frequency range of measurement is 1 MHz to 500 MHz.

A.3. Test parameters

In addition to the parameters listed in annex I of ANSI/TIA/EIA-568-B.2 this annex describes field measurement procedures for the test parameters listed below:

- ANEXT loss, pair-to-pair
- ANEXT loss, power sum

Note: AELFEXT field test procedures are for further study

Note: Mitigation procedures for category 6 channels failing the field test measurements listed in annex I of ANSI/TIA/EIA-568-B.2 measured to 500 MHz are for further study. Mitigation procedures for alien crosstalk are addressed in Annex C.

Annex B

Annex B Test instruments

B.1 Accuracy requirements for level IIIe field testers

The level IIIe requirements in this annex are stated for baseline performance, permanent link and channel configurations. The field tester performance for the channel and permanent link applies to the performance at the reference plane as shown in TIA/EIA-568-B-2.1 figures 1 and 2 respectively.

The methods to compare results from field testers with those obtained using laboratory equipment as defined in TIA/EIA-568-B.2, Annex J Comparison measurement procedures (normative) apply. The observed accuracy from comparison methods is in harmony with predicted measurement accuracy from performance parameters as defined in this annex.

B.1.1 Measurement performance requirements

The requirements in this annex apply in addition to those stated in TIA/EIA-568-B.2-1. Where requirements are tighter, the tighter requirements apply.

Table 3 Level IIIe field tester accuracy performance

Parameter	**Baseline field tester**	**Field tester with Level IIIe permanent link adapter**	**Field tester with Level IIIe channel adapter**	
Dynamic range	3 dB over test limit PP NEXT and FEXT 65 dB PS NEXT and FEXT 62 dB			*dB*
Amplitude resolution	0.1			*dB*
Frequency range and resolution	1 – 31.25 MHz: 150 kHz 31.25–100 MHz:250 kHz 100 MHz – 250 MHz:500 kHz 250 MHz – 500 MHz: 1 MHz			*MHz*
Dynamic Accuracy NEXT	± 0.75			*dB*
Dynamic Accuracy ELFEXT	± 1.0 (FEXT dynamic accuracy is tested to ± 0.75 dB)			*dB*
Source/load return loss	20 – 12.5 log(f/100), 20 dB max. 12.5 dB min	18 – 12.5 log(f/100), 20 dB max., 12 dB min		*dB*
Random Noise Floor	75 – 15 log(f/100), 85 dB max			*dB*
Residual NEXT	65 – 20 log(f/100) (measured to 85 dB max)	60 – 20 log(f/100) (measured to 85 dB max)	54 – 20 log(f/100) (measured to 85 dB max)	*dB*
Residual FEXT	65 – 20 log(f/100) (measured to 85 dB max)	65 – 20 log(f/100) (measured to 85 dB max)	43.1 – 20 log(f/100) (measured to 85 dB max)	*dB*

Output Signal Balance	40 - 20 log(f/100) (measured to 60 dB max)	37 - 20 log(f/100) (measured to 60 dB max)	*dB*
Common Mode Rejection	40 - 20 log(f/100) (measured to 60 dB max)	37 - 20 log(f/100) (measured to 60 dB max)	*dB*
Tracking	± 0.5 dB	1 MHz – 250 MHz: ± 0.5 dB 250 MHz – 500 MHz: ± {0.5 + 0.000667·(f-250)} dB	*dB*
Directivity	(applicable when IL > 3dB) 1 MHz – 300 MHz: 27-7log(f/100), 30 dB max. 300 MHz – 500 MHz: 23.7 dB	25-20log(f/100), 25 dB max, 15 dB min	*dB*
Source Match	20 dB	20-20log(f/100), 20 dB max, 12 dB min	*dB*
Return loss of Termination	(applicable when IL > 3dB) 20-15log(f/100), 25 dB max., 12.5 dB min	16-15log(f/100), 25 dB max, 12 dB min	*dB*

Table 4 Explanation of Notes for Level IIIe specifications

Note	Description
1	The dynamic range for pair-to-pair NEXT and FEXT is 65 dB minimum.
2	The dynamic range for power sum NEXT and power sum FEXT is 62 dB minimum.
3	Dynamic accuracy is tested up to the specified dynamic range for NEXT and FEXT.
4	Dynamic accuracy ELFEXT assumes a dynamic accuracy requirement of ±0.75 dB for FEXT, which is tested, and that the dynamic accuracy performance for insertion loss and FEXT add to the ELFEXT dynamic accuracy shown. It is assumed that the dynamic accuracy performance for ACR equals the dynamic accuracy for ELFEXT.
5	The verification of residual NEXT and FEXT is up to 85 dB maximum. It is assumed that the frequency response changes at a 20 dB/decade rate.
6	Performance verification of Output Signal Balance and Common Mode Rejection is up to 60 dB maximum. It is assumed that the frequency response changes at a 20 dB/decade rate.
7	Permanent link adapter NEXT loss is between the lower and upper ranges of test plugs as specified for category 6 in IEC 60603-7. Compliance with this requirement can also be demonstrated by performing a comparison test as in TIA/EIA-568-B.2, Annex J. In this case, a reference plug qualified per IEC 60603-7 is used to obtain the reference laboratory measurement.
8	Permanent link adapter FEXT loss is between the lower and upper ranges of test plugs as specified for category 6 in IEC 60603-7. Compliance with this requirement can also be demonstrated by performing a comparison test as in TIA/EIA-568-B.2, Annex J. In this case, a reference plug qualified per IEC 60603-7 is used to obtain the reference laboratory measurement.

Annex C

Annex C Alien Crosstalk Mitigation

This annex provides procedures and cabling guidelines designed to mitigate the alien crosstalk between the disturbed pair and disturbing pairs of category 6 channels and permanent links. The annex applies to mitigating alien crosstalk in the event that the alien crosstalk transmission parameters given in either 6.4 or 6.5 are not met. The procedures outlined here are in addition to the procedures in Annex A.

Annex C.1 Alien Crosstalk mitigation procedures

The mitigation actions outlined below are based on four connector channels with category 6 cabling distances > 55 meters or with an insertion loss greater than 19.8 dB at 250 MHz. In the majority of initially non-compliant cases, fewer than all corrective actions will be required. Select the option(s) that is most appropriate for your situation.

1. When selective deployment of 10GBASE-T is possible utilize non-adjacent patch panel positions and separate the equipment cords. The adjacent positions may be used for other applications.

    a. An alternative to separating equipment cords is to utilize equipment cords sufficiently specified to mitigate the alien crosstalk coupling such as Category 6 ScTP and Augmented Category 6.

2. When deployment of 10GBASE-T in adjacent patch panel positions in the telecommunications room is required; identify adjacent patch panel positions for ANEXT measurements.

    a. Adjacent category 6 patch panel positions exhibiting PSNEXT loss greater than TBD.

3. Identify measured patch panel positions to be included in the power sum (Step 2).

    a. The number of disturber ports to be included in the power sum calculation is dependant on the configuration. For any given configuration, the determination of which ports to include can be made based on the pair-to-pair ANEXT contribution to the victim port. All pair to pair ANEXT measurements of any port with a pair to pair ANEXT contribution higher than XX TBD – 20log10(f/100) dB shall be included in the overall power sum.

4. In the event that the alien crosstalk transmission parameters given in either 6.4 or 6.5 are not met in (Step 3), the alien crosstalk may be mitigated by following the procedure outlined below.

    a. Reduce the ANEXT coupling in the first 5 to 20 meters of the horizontal cabling by separating the equipment cords and the patch cords and un-bundling the horizontal cabling: in the case of a telecommunications room un-bundle the cabling to the point it exits the telecommunications room. A significant portion of the ANEXT coupling occurs in the first 20 Meters of cabling.
    b. Reconfigure the cross-connect as an interconnect.
    c. Utilize equipment cords sufficiently specified to mitigate the alien crosstalk coupling such as Category 6 ScTP and Augmented Category 6.
    d. Replace connectors with Augmented Category 6

Annex D

Annex D.1 Alien crosstalk test environment

The alien crosstalk transmission parameters of Alien NEXT and Alien FEXT given in 6.4 and 6.5 are based on the alien crosstalk measurements between cabling channels configured in a six-around-one orientation where the disturbed cable is the central cable and adjacent to all of the other disturbing cables. Except for the restrictions on the number of cables placed in a conduit the cable-to-cable placement is not controlled by specifications resulting in a significant variability in cable-to-cable placement. Two test configurations were designed to control the cable adjacency to be consistent with installed cabling installation practices; a six-around-one configuration consisting of seven cables bound together with tie wraps placed every 5 ft, and a six-around-one configuration of seven cables placed in a conduit with a fill capacity of 40%. The six-around-one cables in both test configurations are terminated in connecting hardware at both ends.