

**DRAFT 1.3**

**February 1, 2005**

**ADDITIONAL GUIDELINES FOR 4-PAIR 100  $\Omega$  CATEGORY 6 CABLING FOR 10GBASE-T APPLICATIONS**

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

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(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  $\Omega$  Category 6 Cabling for 10GBASE-T Applications. The project was assigned to TR-42.7 under Engineering Committee TR-42.

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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 **1 INTRODUCTION**

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

5  
6 This Telecommunications Systems Bulletin includes field test procedures that can be used to  
7 verify if the installed cabling will meet these new guidelines.

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

10 **2 PURPOSE AND SCOPE**

11 This Telecommunications Systems Bulletin describes additional guidelines for 100 Ω, 4-pair  
12 category 6 cabling that have been installed in accordance with TIA/EIA-568-B.2.-1 to support the  
13 proposed IEEE 802.3an 10GBASE-T standard. These guidelines are intended to provide  
14 additional information on the extended frequency transmission performance of category 6 cabling  
15 from 250 MHz up to 500 MHz. It also characterizes the crosstalk coupling between adjacent 4-  
16 pair category 6 cabling channels referred to as alien crosstalk and provides additional guidelines  
17 for field test equipment and field test methods and alien crosstalk mitigation in support of  
18 10GBASE-T. The transmission recommendations included herein are intended to provide a  
19 means to assess installations of category 6 cabling as specified in TIA/EIA-568-B.-1 and  
20 corresponding addenda up to the extended frequencies and additional parameters needed for  
21 10GBASE-T support. The TSB does not place any normative requirements for existing category 6  
22 installations.

23

24 **3 REFERENCES**

25 The following standards are referenced in this text. At the time of publication, the editions  
26 indicated were valid. All standards are subject to revision; parties to agreements based on this  
27 TSB are encouraged to investigate the possibility of applying the most recent editions of the  
28 standards indicated. ANSI and TIA maintain registers of currently valid national standards  
29 published by them.

30

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

33

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

36

37 *ANSI/TIA/EIA-568-B.2-1, Transmission Performance Specifications for 4 Pair 100 Ohm Category*  
38 *6 Cabling*

39 **4 DEFINITIONS, ACRONYMS & ABBREVIATIONS**

40 **4.1 Definitions**

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

45

46 **Alien crosstalk:** A measure of the unwanted signal coupling between adjacent cabling or  
47 components (forward to Definitions Group).

48

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

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

7  
8 **Alien far-end crosstalk(ffs):** A measure of the unwanted signal coupling between pairs in  
9 adjacent cabling from a transmitter at the near-end into a pair measured at the far-end (forward to  
10 Definitions Group).

11  
12 **Power sum Alien far-end crosstalk(ffs):** A computation of the unwanted signal coupling  
13 between pairs in adjacent cabling from multiple transmitters at the near-end into another pair  
14 measured at the far-end. (forward to Definitions Group).

15  
16 **Power sum alien equal level far-end crosstalk(ffs):** A computation of the unwanted signal  
17 coupling between pairs in adjacent cabling from multiple transmitters at the near-end into another  
18 pair measured at the far-end, and relative to the received signal level (forward to Definitions  
19 Group).

## 20 4.2 Acronyms and abbreviations

21 ANEXT Alien Near-end Crosstalk (forward to Definitions Group)

22 PSANEXT Power sum near-end crosstalk (forward to Definitions Group)

23 AFEXT (ffs) Alien Far-end Crosstalk (forward to Definitions Group)

24 PSAFEXT (ffs) Power sum near-end crosstalk (forward to Definitions Group)

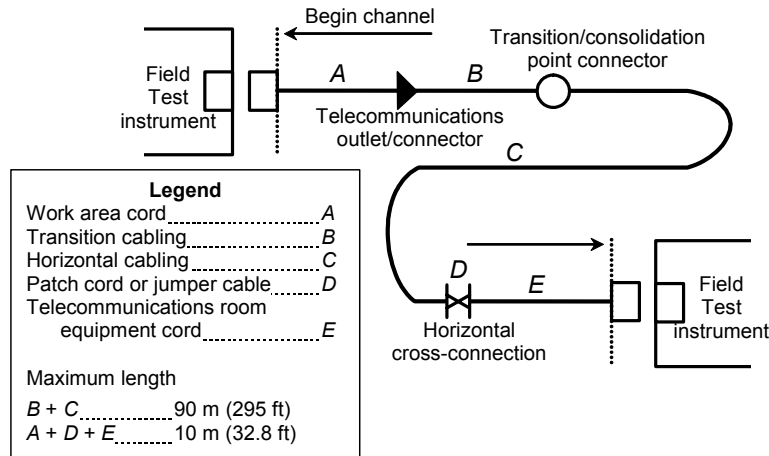
25 PSAELFEXT (ffs) Power sum alien equal level crosstalk (forward to Definitions Group)

## 26 5 TEST CONFIGURATIONS

### 27 5.1 Cabling channel and permanent link test configurations

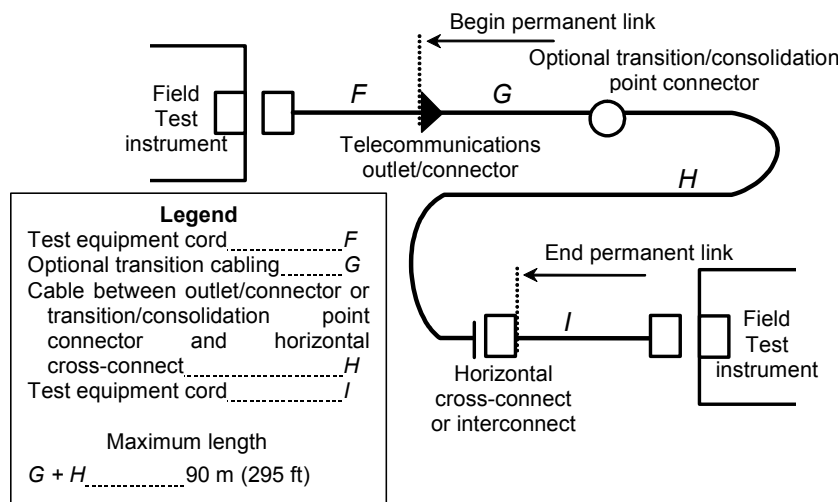
28 Assessment of the channel and permanent link transmission parameters over the frequency  
29 range of 1 MHz to 500 MHz is recommended (see Annex A.).

30  
31 The channel test configuration is used by system designers and users of data communications  
32 systems to verify the performance of the overall channel. The channel includes up to 90 m  
33 (295 ft) of horizontal cable, a work area equipment cord, a telecommunications outlet/connector,  
34 an optional transition/consolidation connector, and two connections in the telecommunications  
35 room. The total length of equipment cords, patch cords or jumpers and work area cords does not  
36 exceed 10 m (33 ft). The channel configuration excludes the connections to the equipment at  
37 each end of the channel. The channel definition does not apply to those cases where the  
38 horizontal cabling is cross-connected to the backbone cabling. A schematic representation of the  
39 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.



1 **6 TRANSMISSION PARAMETERS**

2 **6.1 Insertion Loss**

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

7 **6.1.1 Cabling insertion loss**

8 **6.1.1.1 Channel Insertion Loss**

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

11  
 12

$$INSERTIONLOSS_{channel} \leq 1.924 \times \sqrt{f} + 0.0173 \times f + \frac{0.204}{\sqrt{f}} + 0.0003 \times f^{1.5} \quad \text{dB} \quad (1)$$

13  
 14  
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 18  
 19

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

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

20

21 **6.1.1.2 Permanent Link Insertion Loss**

22 For all frequencies from 1 MHz to 250 MHz, the category 6 permanent link meets the values  
 23 determined using equation (3) as specified in TIA/EIA-568-B.2.-1. For all frequencies (250 < f ≤  
 24 500) the insertion loss of the permanent link should meet the values determined using equation  
 25 (3).

26  
 27

$$(TBD) \text{ dB} \quad (3)$$

28 **6.1.3 Insertion Loss Scaling**

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

33  
 34

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

35

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

36  
 37

38 **6.1.4 Insertion Loss of a Category 6 channel of 55 meters**

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

43

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

**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.

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

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).

$$NEXTchannel \geq 31 - 50 \times \log_{10} \left( \frac{f}{330} \right) \text{dB} \quad (8)$$

**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.

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

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 ( $300 \leq f \leq 500$ ) MHz the permanent pair-to-pair NEXT loss of the cabling should meet the values determined using equation (10)-TBD.

$$NEXT_{permanent\_link} \geq 34 - 48 \times \log_{10} \left( \frac{f}{300} \right) \text{ dB(TBD)} \quad (10)$$

### 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.

$$PSNEXT = -10 \log_{10} (10^{-X1/10} + 10^{-X2/10} + 10^{-X3/10}) \text{ dB} \quad (11)$$

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.

$$PSNEXT_{channel} \geq -20 \times \log_{10} \left( 10^{\frac{42.3-15 \log_{10} \left( \frac{f}{100} \right)}{-20}} + 2 \times 10^{\frac{50-20 \log_{10} \left( \frac{f}{100} \right)}{-20}} \right) \text{ dB} \quad (12)$$

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

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

$$PSNEXT_{channel} \geq 28 - 42 \times \log_{10} \left( \frac{f}{330} \right) \text{ dB} \quad (13)$$

##### 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.

$$PSNEXT_{permanent\_link} \geq -20 \times \log_{10} \left( 10^{\frac{42.3-15 \log_{10} \left( \frac{f}{100} \right)}{-20}} + 10^{\frac{50-20 \log_{10} \left( \frac{f}{100} \right)}{-20}} \right) \text{ dB} \quad (14)$$

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 ( $300 \leq f \leq 500$ ) MHz the permanent link power sum NEXT loss of the cabling should meet the values determined using equation (15)-TBD.

1

$$PSNEXT_{permanent\_link} \geq 31.4 - 40 \times \log_{10} \left( \frac{f}{300} \right) \text{ dB(TBD)} \quad (15)$$

2

### 3 **6.3 ELFEXT and FEXT loss**

4 FEXT loss is a measure of the unwanted signal coupling from a transmitter at the far-end into  
 5 neighboring pairs measured at the near-end. FEXT loss is the ratio of the power coupled from a  
 6 disturbing pair into the disturbed pair relative to the input power at the opposite end of the  
 7 transmission lines determined from measured voltages. This ratio is expressed in dB.

8

9 ELFEXT is expressed in dB as the difference between the measured FEXT loss and the insertion  
 10 loss of the disturbed pair. In addition, since each duplex channel can be disturbed by more than  
 11 one duplex channel, power sum equal level far-end crosstalk (PSELFEXT) is also provided.

#### 12 **6.3.1 Cabling pair-to-pair ELFEXT**

##### 13 **6.3.1.1 Pair-to-pair ELFEXT Channel**

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

18

$$ELFEXT_{channel} \geq -20 \times \log_{10} \left( 10^{\left( \frac{27.8 - 20 \log_{10} \left( \frac{f}{100} \right)}{-20} \right)} + 4 \times 10^{\left( \frac{43.1 - 20 \log_{10} \left( \frac{f}{100} \right)}{-20} \right)} \right) \text{ dB} \quad (16)$$

19

##### 20 **6.3.1.2 Pair-to-pair ELFEXT Permanent Link**

21 For all frequencies from 1 MHz to 250 MHz, the category 6 permanent link ELFEXT meets the  
 22 values determined using equation (14) as specified in TIA/EIA-568-B.2.-1. For all frequencies  
 23 (250 < f ≤ 500) the category 6 permanent link ELFEXT of the permanent link should meet the  
 24 values determined using equation (17).

25

26

$$ELFEXT_{permanent\_link} \geq 20 \times \log_{10} \left( 10^{\left( \frac{27.8 - 20 \log_{10} \left( \frac{f}{100} \right)}{-20} \right)} + 3 \times 10^{\left( \frac{43.1 - 20 \log_{10} \left( \frac{f}{100} \right)}{-20} \right)} \right) \text{ dB} \quad (17)$$

27

#### 28 **6.3.2 Power sum ELFEXT**

29 Power sum equal level far-end crosstalk loss takes into account the combined crosstalk  
 30 (statistical) on a receive pair from all far-end disturbers operating simultaneously. The power sum  
 31 equal level far-end crosstalk (PSELFEXT) loss is calculated in accordance with ASTM D4566 as  
 32 a power sum on a selected pair from all other pairs as shown in equation (18) for the case of 4-  
 33 pair cable.

34

$$PSELFEXT = -10 \log_{10} \left( 10^{-X1/10} + 10^{-X2/10} + 10^{-X3/10} \right) \text{ dB} \quad (18)$$

35

36

37

38

where:

39

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

1 **6.3.2.1 Cabling power sum ELFEXT**

2 **6.3.2.1.1 Power sum ELFEXT Channel**

3 For all frequencies from 1 MHz to 250 MHz, the category 6 channel power sum ELFEXT meets  
 4 the values determined using equation (16) as specified in TIA/EIA-568-B.2.-1. For all frequencies  
 5 (250 < f ≤ 500) the category 6 channel power sum ELFEXT should meet the values determined  
 6 using equation (19).  
 7

8 
$$PSELFEXT_{channel} \geq -20 \times \log_{10} \left( 10^{\frac{24.8 - 20 \log_{10} \left( \frac{f}{100} \right)}{-20}} + 4 \times 10^{\frac{40.1 - 20 \log_{10} \left( \frac{f}{100} \right)}{-20}} \right) \text{ dB} \quad (19)$$

9 **6.3.2.1.2 Power sum ELFEXT Permanent Link**

10 For all frequencies from 1 MHz to 250 MHz, the category 6 permanent link power sum ELFEXT  
 11 meets the values determined using equation (17) as specified in TIA/EIA-568-B.2.-1. For all  
 12 frequencies (250 < f ≤ 500) the category 6 permanent link power sum ELFEXT should meet the  
 13 values determined using equation (20).  
 14

15 
$$PSELFEXT_{permanent\_link} \geq 20 \times \log_{10} \left( 10^{\frac{24.8 - 20 \log_{10} \left( \frac{f}{100} \right)}{-20}} + 3 \times 10^{\frac{40.1 - 20 \log_{10} \left( \frac{f}{100} \right)}{-20}} \right) \text{ dB} \quad (20)$$

16 **6.4 Alien NEXT loss**

17 Alien NEXT loss is a measure of the unwanted signal coupling between pairs in adjacent cabling  
 18 from transmitters at the near-end into a pair measured at the near-end. Alien NEXT loss is  
 19 expressed in dB relative to the transmit signal level. In addition, since each duplex channel can  
 20 be disturbed by more than one duplex channel in adjacent cabling, power sum Alien near-end  
 21 crosstalk (PS ANEXT) loss is also provided.  
 22

23 Editors Note: Alien NEXT Measurement procedure is under study.

24 **6.4.1 Pair-to-pair ANEXT loss (ffs)**

25 **6.4.1.1 Cabling pair-to-pair ANEXT loss**

26 **6.4.1.1.1 ANEXT Channel Equation** (21)

27 **6.4.1.1.2 ANEXT Permanent Link Equation** (22)

28 **6.4.2 Power sum Alien NEXT loss**

29 Power sum Alien near-end crosstalk loss takes into account the combined crosstalk (statistical)  
 30 on a receive pair from near-end disturbers in adjacent cables operating simultaneously. The  
 31 power sum near-end crosstalk (PSANEXT) loss is determined by summing the power of the  
 32 individual pair-to-pair differential Alien NEXT loss values over the frequency range 1 MHz to 500  
 33 MHz as follows in equation (21):  
 34

35 
$$-10 \times \log_{10} \sum_{i=1}^n 10^{\frac{-AN(f)_i}{10}} \quad \text{(dB)} \quad (23)$$

36 where

37

38 AN(f)<sub>i</sub> is the magnitude in dB of PS ANEXT loss at frequency f of pair combination i

1 i is the pair-to-pair combination (1 to n)  
 2 n is the number of pair-to-pair combinations between adjacent cabling  
 3

4 **6.4.2.1 Power sum Alien NEXT loss for a Category 6 channel of 100 meters**

5 For a 10GBASE-T 100 meter Category 6 channel with the maximum insertion loss specified in  
 6 6.1 the PS ANEXT loss between the disturbed duplex channel and the disturbing duplex  
 7 channels in adjacent cabling should meet the values determined using equation (24).  
 8

9 
$$\text{PS ANEXT} > \begin{cases} 62 - 10 \cdot \log_{10}(f\text{MHz}/100) & 1 \text{ MHz} \leq f \leq 100 \text{ MHz} \\ 62 - 15 \cdot \log_{10}(f\text{MHz}/100) & 100 \text{ MHz} < f \leq 500 \text{ MHz} \end{cases} \quad (24)$$
  
 10  
 11

12 **6.4.2.2 Power sum Alien NEXT loss Adjustment**

13 The adjusted PS ANEXT loss requirement is determined by first calculating the PS  
 14 ANEXT\_constant and utilizing the constant in the PS ANEXT limit line model.  
 15

16 The PS ANEXT\_constant is defined by the following equation (25):  
 17

18 
$$\text{PSANEXT\_Constant} = 62 - (\text{Cat6\_IL\_250MHz} - \text{SCat6\_IL\_250MHz}) \times \frac{15}{15.6} \text{ dB} \quad (25)$$
  
 19  
 20

21 where

22 Cat6\_IL\_250MHz is the Category 6 insertion loss at 250 MHz for a 100 meter channel

23 SCat6\_IL\_250MHz is the scaled Category 6 insertion at 250 MHz

24 **6.4.2.3 PS ANEXT for a Category 6 channel of 55 meters**

25 For a 10GBASE-T 55 meter Category 6 channel with the maximum insertion loss specified in  
 26 6.1.3 the PS ANEXT loss between the disturbed duplex channel and the disturbing duplex  
 27 channels in adjacent cabling should meet the values determined using equation (26).  
 28

29 
$$\text{PS ANEXT} > \begin{cases} 47 - 10 \cdot \log_{10}(f\text{MHz}/100) & 1 \text{ MHz} \leq f \leq 100 \text{ MHz} \\ 47 - 15 \cdot \log_{10}(f\text{MHz}/100) & 100 \text{ MHz} < f \leq 500 \text{ MHz} \end{cases} \quad (26)$$
  
 30

31 **6.5 Alien FEXT and Alien ELFEXT loss**

32 Alien FEXT is a measure of the unwanted signal coupling from a transmitter at the far-end into  
 33 neighboring pairs measured at the near-end. Alien FEXT loss is the ratio of the power coupled  
 34 from a disturbing pair into the disturbed pair relative to the input power at the opposite end of the  
 35 transmission lines determined from measured voltages. This ratio is expressed in dB.  
 36

37 Alien ELFEXT is expressed in dB as the difference between the measured Alien FEXT loss and  
 38 the insertion loss of the disturbed pair. In addition, since each duplex channel can be disturbed  
 39 by more than one duplex channel in adjacent cabling power sum Alien near-end crosstalk (PS  
 40 AELFEXT) loss is also provided.  
 41

1 **6.5.1 Pair-to-pair AELFEXT loss (ffs)**

2 **6.5.1.1 Cabling pair-to-pair AELFEXT loss**

3 **6.5.1.1.1 AELFEXT Channel**

4 **6.5.1.1.2 AELFEXT Permanent Link**

5 **6.5.2 Power sum Alien ELFEXT loss**

6 Power sum alien equal level far-end crosstalk loss takes into account the combined crosstalk  
 7 (statistical) on a receive pair from all far-end disturbers operating simultaneously. The power sum  
 8 alien equal level far-end crosstalk (PS AELFEXT) loss is determined by summing the power of  
 9 the individual pair-to-pair differential Alien ELFEXT loss values over the frequency range 1 MHz  
 10 to 500 MHz as follows in equation (27):

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

12 where

13 AEL(f)<sub>i</sub> is the magnitude in dB of PS AELFEXT loss at frequency f of pair combination i

14 i is the pair-to-pair combination (1 to n)

15 n is the number of pair-to-pair combinations between adjacent cable

16 **6.5.2.1 Power sum Alien ELFEXT loss for a Category 6 channel of 100 meters**

17 For a 10GBASE-T 100 meter Category 6 channel with the maximum insertion loss specified in  
 18 6.1 the PS AELFEXT loss between the disturbed duplex channel and the disturbing duplex  
 19 channels in adjacent cabling should meet the values determined using equation (28).  
 20  
 21  
 22

$$PSAELFEXT \geq 37 - 20 \times \log_{10} \left( \frac{f}{100} \right) \text{ dB} \quad (28)$$

23 **6.5.2.2 Power sum Alien ELFEXT Adjustment (ffs)**

24 **6.5.2.3 PS AELFEXT loss for a Category 6 channel of 55 meters**

25 For a 10GBASE-T 55 meter Category 6 channel with the maximum insertion loss specified in  
 26 6.1.3 the PS AELFEXT loss between the disturbed duplex channel and the disturbing duplex  
 27 channels in adjacent cabling should meet the values determined using equation (29).  
 28  
 29

$$PSAELFEXT \geq 33.6 - 20 \times \log_{10} \left( \frac{f}{100} \right) \text{ dB} \quad (29)$$

1 **6.6 Return Loss**

2 Return loss is a measure of the reflected energy caused by impedance mismatches in the cabling  
 3 system and is especially important for applications that use simultaneous bi-directional  
 4 transmission. Return loss is expressed in dB relative to the reflected signal level.

5 **6.6.1 Cabling Return Loss**

6 **6.6.1.1 Channel return loss**

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

10 **Table 1 Category 6 channel return loss**

11

Frequency (MHz)	Return Loss (dB)
$1 \leq f < 10$	19
$10 \leq f < 40$	$24 - 5\log_{10}(f)$
$40 \leq f \leq 250$	$32 - 10\log_{10}(f)$
$250 < f < 400$	$32 - 10\log_{10}(f)$
$400 \leq f \leq 500$	6

12

13 **6.6.1.2 Permanent link return loss**

14

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

18 **Table 2 Category 6 permanent link return loss**

19

Frequency (MHz)	Return Loss (dB)
$1 \leq f < 3$	$21 + 4\log_{10}(f/3)$
$3 \leq f < 10$	21
$10 \leq f < 40$	$26 - 5\log_{10}(f)$
$40 \leq f \leq 250$	$34 - 10\log_{10}(f)$
$250 < f < 400$	$10 - 20\log_{10}(f/250)$
$400 \leq f \leq 500$	6

20 **6.7 Propagation delay/delay skew**

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

27 **6.7.1 Cabling propagation delay**

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

30

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



1 **6.7.2 Cabling propagation delay skew**

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

4  
5 The maximum propagation delay skew for a category 6 permanent link configuration does not  
6 exceed 44 ns as specified in TIA/EIA-568-B.2.-1.

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1 **Annex A**

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2 **Annex A Cabling (field) measurement procedures**

3

4 **A.1 General**

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

7

8 **A.2 Frequency range**

9 Frequency range of measurement is 1 MHz to 500 MHz.

10

11 **A.3. Test parameters**

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

14

- 15 • ANEXT loss, pair-to-pair
- 16 • ANEXT loss, power sum

17

18 Note: AELFEXT field test procedures are for further study

19

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

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1 **Annex B**

2 **Annex B Test instruments**

3

4 **B.1 Accuracy requirements for level IIIe field testers**

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

9

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

14

15 **B.1.1 Measurement performance requirements**

16

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

19

20

Table 3 Level IIIe field tester accuracy performance

21

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 Balance	Signal	40 - 20 log(f/100) (measured to 60 dB max)	37 - 20 log(f/100) (measured to 60 dB max)	dB
Common Rejection	Mode	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

1

2 **Table 4** Explanation of Notes for Level IIIe specifications

3

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.

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1 **Annex C**

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2 **Annex C Alien Crosstalk Mitigation**

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

8

9 Annex C.1 Alien Crosstalk mitigation procedures

10

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

15

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

19

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

23

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

27

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

30

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

32

- 33 a. The number of disturber ports to be included in the power sum calculation is  
34 dependant on the configuration. For any given configuration, the determination of  
35 which ports to include can be made based on the pair-to-pair ANEXT contribution  
36 to the victim port. All pair to pair ANEXT measurements of any port with a pair to  
37 pair ANEXT contribution higher than  $XX \text{ TBD} - 20\log_{10}(f/100)$  dB shall be  
38 included in the overall power sum.

39

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

43

- 44 a. Reduce the ANEXT coupling in the first 5 to 20 meters of the horizontal cabling  
45 by separating the equipment cords and the patch cords and un-bundling the  
46 horizontal cabling; in the case of a telecommunications room un-bundle the  
47 cabling to the point it exits the telecommunications room. A significant portion of  
48 the ANEXT coupling occurs in the first 20 Meters of cabling.

49

- b. Reconfigure the cross-connect as an interconnect.

50

- c. Utilize equipment cords sufficiently specified to mitigate the alien crosstalk  
51 coupling such as Category 6 ScTP and Augmented Category 6.

52

- d. Replace connectors with Augmented Category 6

1 **Annex D**

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2  
3 Annex D.1 Alien crosstalk test environment  
4

5 The alien crosstalk transmission parameters of Alien NEXT and Alien FEXT given in 6.4 and 6.5  
6 are based on the alien crosstalk measurements between cabling channels configured in a six-  
7 around-one orientation where the disturbed cable is the central cable and adjacent to all of the  
8 other disturbing cables. Except for the restrictions on the number of cables placed in a conduit  
9 the cable-to-cable placement is not controlled by specifications resulting in a significant variability  
10 in cable-to-cable placement. Two test configurations were designed to control the cable  
11 adjacency to be consistent with installed cabling installation practices; a six-around-one  
12 configuration consisting of seven cables bound together with tie wraps placed every 5 ft, and a  
13 six-around-one configuration of seven cables placed in a conduit with a fill capacity of 40%. The  
14 six-around-one cables in both test configurations are terminated in connecting hardware at both  
15 ends.  
16