THIS IS THE FINAL DRAFT OF SUGGESTED ENTRIES IN ISO TR24750 RELATED TO ALIEN CROSSTALK REQUIREMENTS PER IEEE802.3an
***April 4, 2006*.**

This draft includes suggestions by George Zimmerman, Chris Diminico, Masood Shariff and Jo Walling, and is also based on guidelines per ISO/IEC liaison letter to IEEE802.3 number 3N779.

Additional comments, if any, to henriecus.koeman@flukenetworks.com are appreciated.

Alien Noise

6.7.1 General

Power-Sum Alien NEXT (PS ANEXT) and Power-Sum Alien Attenuation to Crosstalk Ratio FEXT Far End (PS AACR-F) are specified in the following clause, in accordance with IEEE802.3 10GBASE-T.

Notes
1) Formulae used in 6.7.3 and 6.7.4 for alien crosstalk limits are numerically different to those currently used by IEEE 802.3 10GBASE-T; however they are technically equivalent, more concise and better suited for a cabling document.
2) To represent the impact of PS AFEXT on the signal-to-noise ratio, IEEE802.3 10GBASE-T uses for PS AELFEXT the difference of the PS AFEXT and the disturbed channel insertion loss. ISO/IEC 11801 uses the disturbing channel insertion loss for the same parameter. The suggested term in ISO TR24750 for the IEEE802.3 10GBASE-T intended parameter is PS AACR-F.

There are separate requirements for PS ANEXT and PS AACR-F applicable over a 1 MHz to 500 MHz frequency range as stated in clause 6.7.2 for PS ANEXT and in clause 6.7.3 for PS AACR-F. In case one or both requirements are not met, compliance with 10GBASE-T requirements can be achieved by the requirement for PS Alien Crosstalk (PS AXtalk) average margin applicable over a 10 MHz to 400 MHz frequency range as stated in clause 6.7.5.

6.7.2 PS ANEXT requirements

6.7.2.1 Computation of PS ANEXT from ANEXT measurements

The PS ANEXT frequency response of pair **k** of a disturbed channel is computed per equation (7).

$$\mathrm{PSANEXT}_{k}(f) = -10 \cdot \log\left(\sum_{j=1}^{N} \sum_{i=1}^{n} 10^{\frac{-\left(\mathrm{ANEXT}_{k,i,j}(f)\right)}{10}} \right) \qquad (7)$$

where

f is the frequency

k is the number of the disturbed pair (in a disturbed channel);

i is the number of a disturbing pair (in a disturbing channel);

j is the number of a disturbing channel

N is the total number of disturbing channels;

n is the total number of disturbing pairs (4) in each of N disturbing channels;

$\mathrm{ANEXT}_{k,i,j}(f)$ is the frequency response of the alien NEXT coupled from pair **i** of disturbing channel **j** into pair **k** of the disturbed channel.

NOTE Pairs external to the disturbed channel are all those pairs surrounding the channel that belong to other disturbing channels in close proximity that could disturb the disturbed channel.

The average PS ANEXT frequency response of all wire pairs is computed by averaging the values of each wire pair expressed in dB as in equation (8).

$$\mathrm{PSANEXT}_{avg}(f) = \frac{1}{4} \sum_{k=1}^{4} \mathrm{PSANEXT}_{k}(f) \qquad (8)$$

6.7.3.2 PS ANEXT limits

To support 10GBASE-T, the PS ANEXT for each pair in a channel shall meet or exceed the limits computed, to one decimal place, using the formulae in Table 15. The limits shown in Table 16 are for information only and are derived from the formulae at key frequencies.

Table 15 – Formulae for PS ANEXT limits for a channel

<table>
<tr><th>Frequency
(MHz)</th><th colspan="2">Minimum PS ANEXT
(dB)</th></tr>
<tr><td>1 ≤ f ≤ 100</td><td>Max{27,45 + IL(250)/1,04 and 33,5} – 10log(f/100)</td><td rowspan="2">For every pair of the disturbed channel</td></tr>
<tr><td>100 < f ≤ 500</td><td>Max{27,45 + IL(250)/1,04 and 33,5} – 15log(f/100)</td></tr>
<tr><td>1 ≤ f ≤ 100</td><td>Max{29,70 + IL(250)/1,04 and 35,75} – 10log(f/100)</td><td rowspan="2">For the average of the 4 pairs of the disturbed channel</td></tr>
<tr><td>100 < f ≤ 500</td><td>Max{29,70 + IL(250)/1,04 and 35,75} – 15log(f/100)</td></tr>
<tr><td colspan="3">Where IL(250) is the disturbed channel insertion loss at 250 MHz in dB rounded to one decimal place.
The average IL(250) of all wire pairs in the disturbed channel is used to compute the PS ANEXT limits applicable to every wire pair and the average of the 4 wire pairs.
For pass/fail evaluation of measured PS ANEXT performance, calculated values greater than 67 dB shall revert to a minimum requirement of 67,0 dB.</td></tr>
</table>

Table 16 – PS ANEXT limits for a channel at key frequencies.

<table>
<tr><th></th><th colspan="6">Minimum PS ANEXT (dB)</th></tr>
<tr><td>Frequency (MHz)</td><td>1,0</td><td>16,0</td><td>100,0</td><td>250,0</td><td>500,0</td><td></td></tr>
<tr><td>IL(250) = 20,3 dB; L = 55 m</td><td>67,0</td><td>55,0</td><td>47,0</td><td>41,0</td><td>36,5</td><td rowspan="3">For every pair of the disturbed channel</td></tr>
<tr><td>IL(250) = 33,8 dB; L = 100 m</td><td>67,0</td><td>67,0</td><td>60,0</td><td>54,0</td><td>49,5</td></tr>
<tr><td>IL(250) = 35,9 dB; L = 100 m</td><td>67,0</td><td>67,0</td><td>62,0</td><td>56,0</td><td>51,5</td></tr>
<tr><td>IL(250) = 20,3 dB; L = 55 m</td><td>67,0</td><td>57,25</td><td>49,25</td><td>43,25</td><td>38,75</td><td rowspan="3">For the average of the 4 pairs of the disturbed channel</td></tr>
<tr><td>IL(250) = 33,8 dB; L = 100 m</td><td>67,0</td><td>67,0</td><td>62,25</td><td>56,25</td><td>51,75</td></tr>
<tr><td>IL(250) = 35,9 dB; L = 100 m</td><td>67,0</td><td>67,0</td><td>64,25</td><td>58,25</td><td>53,75</td></tr>
</table>

NOTES.

1) The IEEE 802.3 10GBASE-T PS NEXT constants can be seen in bold in Table 16.
2) Value of PS ANEXT at frequencies for which the measured channel insertion loss is below 4,0 dB are for information only.

6.7.3 PS AACR-F requirements

6.7.3.1 Computation of PS AACR-F from AFEXT and Insertion Loss measurements

The measured pair-to-pair alien FEXT values of a wire pair **k** in a disturbed channel from the disturbing channel **j** are normalized by the difference of the insertion losses of disturbing and disturbed channels and a length scaling term as in equations (9) and (10).

If $IL_{\mathrm{k}}(f) - IL_{\mathrm{i,\,j}}(f) > 0$ then:

$$AFEXT\mathrm{norm}_{\mathrm{k,i,\,j}}(f) = AFEXT_{\mathrm{k,i,\,j}}(f) + IL_{\mathrm{k}}(f) - IL_{\mathrm{i,\,j}}(f) - 10 \cdot \log\left(\frac{IL_{\mathrm{k}}(f)}{IL_{\mathrm{i,\,j}}(f)}\right) \qquad (9)$$

Otherwise:

$$AFEXT\mathrm{norm}_{\mathrm{k,i,\,j}}(f) = AFEXT_{\mathrm{k,i,\,j}}(f) \qquad (10)$$

where:

f is the frequency

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

i is the number of a disturbing pair in a disturbing channel

j is the number of a disturbing channel

$AFEXT_{\mathrm{k,i,\,j}}(f)$ is frequency response of the measured pair-to-pair FEXT in dB to wire pair k of the disturbed channel from wire pair i in disturbing channel j.

$IL_{\mathrm{k}}(f)$ is the measured frequency response of the insertion loss in dB of wire pair k of the disturbed channel.

$IL_{\mathrm{i,\,j}}(f)$ is the measured frequency response of the insertion loss in dB of wire pair i of disturbing channel j.

Editor's note: practically for

- $IL_{\mathrm{k}}(f)$ ***one can use the average insertion loss of all 4 wire pairs of the disturbed channel.***
- $IL_{\mathrm{i,\,j}}(f)$ ***one can use the average insertion loss of all 4 wire pairs of the disturbing channel.***

- ***The ratio*** $\frac{IL_k(f)}{IL_{i,j}(f)}$ ***one can use the average insertion losses @ 250 MHz of all 4 pairs of the disturbed*** IL_k ***and disturbing channel*** $IL_{i,j}$ ***since the ratio is essentially frequency insensitive.***

The frequency response of the power sum alien *FEXT* of pair k $PSAFEXT_k(f)$ of a disturbed channel is computed per equation (11).

$$PSAFEXT_k(f) = -10\log\left(\sum_{j=1}^{N}\sum_{i=1}^{n} 10^{\frac{-\left(AFEXTnorm_{k,i,j}(f)\right)}{10}}\right) \quad (11)$$

where:

n is the number of wire pairs in disturbing channel j

N is the total number if disturbing channels.

The $\mathrm{PS\ AACR\_F}_k(f)$ frequency response of pair **k** of a disturbed channel is computed per equation (12).

$$\mathrm{PS\ AACR\_F}_k(f) = \mathrm{PS\ AFEXT}_k(f) - \mathrm{IL}_{avg}(f) \quad (12)$$

where

f is the frequency

k is the number of the disturbed pair

$\mathrm{IL}_{avg}(f)$ is the frequency response of the average insertion loss of all wire pairs expressed in dB. When required, it shall be measured according to IEC 61935-1. The frequency response of the average insertion loss is computed per equation (13).

$$\mathrm{IL}_{avg}(f) = \frac{1}{4}\sum_{k=1}^{4}\mathrm{IL}_k(f) \quad (13)$$

NOTE Pairs external to the disturbed channel are all those pairs surrounding the channel that belong to other disturbing channels in close proximity that could disturb the disturbed channel.

The frequency response of the average PS AFEXT of all wire pairs is computed by averaging the values of each wire pair expressed in dB as in equation (14).

$$\mathrm{PSAFEXT}_{avg}(f) = \frac{1}{4}\sum_{k=1}^{4}\mathrm{PSAFEXT}_{k}(f) \quad (14)$$

The frequency response of $\mathrm{PSAACR\_F}_{avg}(f)$ is computed per equation (15).

$$\mathrm{PSAACR\_F}_{avg}(f) = \mathrm{PSAFEXT}_{avg}(f) - \mathrm{IL}_{avg}(f) \quad (15)$$

6.7.3.2 PS AACR-F limits

To support 10GBASE-T, the PS AACR-F for each pair in a channel shall meet or exceed the limits computed, to one decimal place, using the formulae in Table 17. The limits shown in Table 18 are derived from the formulae at key frequencies and are for information only.

Table 17 – Formulae for PS AACR-F limits for a channel

Frequency (MHz)	Minimum PS AACR-F (dB)	
1 ≤ f ≤ 500	Max{22,21 + IL(250)/2,29 and 32,5} – 20log(f/100)-10log(L/100)	For every pair
1 ≤ f ≤ 500	Max{26,21 + IL(250)/2,29 and 36,5} – 20log(f/100)-10log(L/100)	For the average of the 4 pairs per disturbed channel
IL(250) is the channel insertion loss at 250 MHz in dB rounded to one decimal place. L is the physical channel length in m. For the purpose of field measurements $L = 2,77 \cdot \sqrt{f}$, where **f** is the frequency in MHz. The average measured IL(250) of all wire pairs of the disturbed channel is used in limit calculations applicable to all wire pairs. For pass/fail evaluation of measured PS AACR-F performance, when the PS AFEXT exceeds 72-15lg(f/100) or 67,0 dB, the calculated PS AACR-F result shall be for information only.		

Table 18 – PS AACR-F limits for a channel at key frequencies.

	Minimum PS AACR-F (dB)					
Frequency (MHz)	1,0	16,0	100,0	250,0	500,0	
IL(250) = 20,3 dB; L = 55 m	65,7	49,6	**33,7**	25,7	19,7	For every pair
IL(250) = 33,8 dB; L = 100 m	64,8	52,9	**37,0**	29,0	12,2	
IL(250) = 35,9 dB; L = 100 m	64,7	53,8	**37,9**	29,9	8,1	
IL(250) = 20,3 dB; L = 55 m	65,7	53,6	37,7	29,7	19,7	For the average of the 4 pairs per disturbed channel
IL(250) = 33,8 dB; L = 100 m	64,8	56,9	41,0	33,0	12,2	
IL(250) = 35,9 dB; L = 100 m	64,7	57,6	41,9	33,7	8,1	

NOTE

The IEEE 802.3 10GBASE-T PS AACR-F constants can be seen in bold in Table 19.

6.7.4 Examples of implementations at key IL(250)

Table 19 provides examples of channel lengths that will support 10GBASE-T on category 6 and category 7 cabling, connectors and cords as specified in ISO/IEC 11801:2002 and the noise levels specified in 6.8 and 6.9.

Table 19: Examples of implementations at key insertion loss

Channel length (m)	Component category	Length of fixed cable + cord (m + m)	Noise constant at 100 MHz (dB)	
			PS ANEXT	PS AACR-F
IL at 250 MHz = 20,3 dB				
55 [a]	6	42,8 + 10	47	33,7
55 [a]	7	45,8 + 10		
IL at 250 MHz = 33,8 dB				
100 [b]	6	42,8 + 10	60	37
100 [b]	7	45,8 + 10		
IL at 250 MHz = 35,9 dB				
100 [b]	6	90 + 10	62	37,9
100 [b]	7	90 + 10		
[a] approximately 55 m [b] approximately 100 m				

6.7.5 PS AXtalk margin requirements

PS AXtalk requirements are satisfied when both the PS ANEXT as defined in clause 6.7.2 and PS AACR-F as defined in clause 6.7.3 are both satisfied. If either PS ANEXT or PS AACR-F requirements are not met, the overall requirements for PS AXtalk may be satisfied through computations of average margins. There are separate average margin computations that apply to each individual wire pair and to the average of all wire pairs.

The computations in subclauses 6.7.5.1 through 6.7.5.3 are performed to determine the overall pass/fail condition stated in subclause 6.7.5.4.

6.7.5.1 Power Backoff Corrections to measured PP Alien Crosstalk results

The input signal power to each 10GBASE-T channel is adjusted based on the average insertion loss of all wire pairs @ 250 MHz of that channel. In short channels input signal power is reduced as defined in IEEE802.3 10GBASE-T. Table 1 is the back-off table with the scaled insertion loss values for each of the received signal power at the MDI shown in this table in column 1.

Table 1: Minimum power back-off per IEEE802.3 10GBASE-T.

Received signal power P (dBm) at MDI on worst pair	Length L (m) (Reference)	Minimum Power Backoff (dB)	Insertion Loss IL (dB) (Reference)
-1,1 < P	0 ≤ L < 35	10	IL < 13,40
-2,3 < P ≤ -1,1	35 ≤ L < 45	8	13,40 ≤ IL < 16,87
-3,3 < P ≤ -2,3	45 ≤ L < 55	6	16,87 ≤ IL < 20,33
-4,2 < P ≤ -3,3	55 ≤ L < 65	4	20,33 ≤ IL < 23,80
-5,0 < P ≤ -4,2	65 ≤ L < 75	2	23,80 ≤ IL < 27,27
P ≤ -5,0	75 ≤ L	0	27,27 ≤ IL

For the purpose of PS AXtalk margin calculations only, the pair-to-pair alien crosstalk measurements shall be corrected for differences in power back-off in disturbed and disturbing channels.

This correction is given by equation (16).

$$\mathrm{PBOdiff}_{j} = \mathrm{PBO}_{j} - \mathrm{PBO} \qquad (16)$$

where

PBO_{j} is the power back-off applicable to a disturbing channel **j**, and

PBO is the power back-off applicable to a disturbed channel

The overall computed PS ANEXT frequency response for margin computation purposes applicable to each wire pair is given by $\mathrm{PSANEXTm}_{k}(f)$ in equation (17).

$$\mathrm{PSANEXTm}_{k}(f) = -10 \cdot \log\left(\sum_{j=1}^{N} \sum_{i=1}^{n} 10^{\frac{-\left(\mathrm{ANEXT}_{k,i,j}(f) + \mathrm{PBOdiff}_{j}\right)}{10}} \right) \qquad (17)$$

$\mathrm{PBOdiff}_{j}$ is the difference in power back-off of the disturbed channel and disturbing channel **j**.

The overall computed frequency response of PS AFEXT for margin computation purposes applicable to each wire pair is given in equation (18).

$$\text{PSAFEXTm}_k(f) = -10 \cdot \log\left(\sum_{j=1}^{N} \sum_{i=1}^{n} 10^{\frac{-\left(\text{AFEXT}_{k,i,j}(f) + \text{PBOdiff}_j\right)}{10}} \right) \quad (18)$$

The frequency response of PS AXtalk of a wire pair **k** of a disturbed channel is computed from the measured PS ANEXT and PS AFEXT per equation (19).

$$\text{PSAXtalk}_k(f) = -10 \cdot \log\left(10^{\frac{-\text{PSANEXTm}_k(f)}{10}} + 10^{\frac{-\text{PSAFEXTm}_k(f)}{10}} \right) \quad (19)$$

where:

f is the frequency

$\text{PSANEXTm}_k(f)$ is the frequency response of PS ANEXT to wire pair **k** of the disturbed channel as computed in equation (15).

$\text{PSAFEXTm}_k(f)$ is the frequency response of PS AFEXT to wire pair **k** of the disturbed channel as computed in equation (16).

For the average frequency response of PS AXtalk applicable to each wire pair, the computation is per equation (20).

$$\text{PSAXtalk}_{\text{avg}}(f) = \frac{1}{4} \sum_{k=1}^{4} \left(-10 \cdot \log\left(10^{\frac{-\text{PSANEXTm}_k(f)}{10}} + 10^{\frac{-\text{PSAFEXTm}_k(f)}{10}} \right) \right) \quad (20)$$

6.7.5.2 PS AXtalk limits

The pass/fail limit as a function of frequency for the PS AXtalk applicable to each wire pair **k** shall be computed per equation (21).

$$\mathrm{PSAXtalk}_{\mathrm{limit,k}}(f) = -10 \cdot \log\left(10^{\frac{-\left(\mathrm{PSANEXT}_{\mathrm{limit,k}}(f)+2{,}5\right)}{10}} + 10^{\frac{-\left(\mathrm{PSAACR\_F}_{\mathrm{limit,k}}(f)+\mathrm{IL}_{\mathrm{avg}}(f)\right)}{10}} \right) \qquad (21)$$

where:

f is the frequency

$\mathrm{PSANEXT}_{\mathrm{limit,k}}(f)$ is the PS ANEXT limit as a function of frequency applicable to each wire pair **k** as computed per the applicable equations in Table 15.

$\mathrm{PSAACR\_F}_{\mathrm{limit,k}}(f)$ is the PS AACR-F limit as a function of frequency applicable to each wire pair **k** as computed per the applicable equations in Table 17.

$\mathrm{IL}_{\mathrm{avg}}(f)$ is the measured average insertion loss as a function of frequency of all wire pairs of the disturbed channel computed per equation (11).

NOTE. The 2,5 dB addition is the estimated peak-to-average difference of the PS ANEXT response applicable to each wire pair **k**.

The pass/fail limit for the PS AXtalk as a function of frequency, applicable to the average of all wire pairs shall be computed as in eq (22):

$$\mathrm{PSAXtalk}_{\mathrm{limit,avg}}(f) = -10 \cdot \log\left(10^{\frac{-\left(\mathrm{PSANEXT}_{\mathrm{limit,k}}(f)+3{,}5\right)}{10}} + 10^{\frac{-\left(\mathrm{PSAACR\_F}_{\mathrm{limit,k}}(f)+4+\mathrm{IL}_{\mathrm{avg}}(f)\right)}{10}} \right) \qquad (22)$$

where:

$\mathrm{PSANEXT}_{\mathrm{limit,k}}(f)$ is the PS ANEXT limit as a function of frequency applicable to the a wire pair as computed per the applicable equations in Table 15.

$\mathrm{PSAACR\_F}_{\mathrm{limit,k}}(f)$ is the PS AACR_F limit as a function of frequency applicable to each wire pair **k** as computed per the applicable equations in Table 17.

NOTE. The 3,5 dB addition is the estimated peak-to-average difference of the PS ANEXT response applicable to the average of all wire pairs. The 4 dB addition is the increase of the PS AACR-F requirement applicable to the average of all 4 wire pairs relative to the minimum requirement applicable to each wire pair.

6.7.5.3 PS AXtalk average margin calculations

The margin of the PS AXtalk of wire pair **k** as a function of frequency is computed per equation (23).

$$\mathrm{PSAXtalk}_{\mathrm{Margin,\,k}}(f) = \mathrm{PSAXtalk}_{\mathrm{k}}(f) - \mathrm{PSAXtalk}_{\mathrm{lim,\,k}}(f) \qquad (23)$$

The 10 MHz to 400 MHz range is divided in **int** contiguous, non-overlapping, frequency intervals in the 10 MHz to 400 MHz frequency range.

The average margin of each measurement frequency interval **int** is computed per equation (24).

$$\mathrm{PSAXtalk}_{\mathrm{int,k}} = \frac{\begin{Bmatrix} \mathrm{PSAXtalk}_{\mathrm{Margin,k}}(\mathrm{high\_freq}_{\mathrm{int}}) + \\ \mathrm{PSAXtalk}_{\mathrm{Margin,k}}(\mathrm{low\_freq}_{\mathrm{int}}) \end{Bmatrix} \cdot (\mathrm{high\_freq}_{\mathrm{int}} - \mathrm{low\_freq}_{\mathrm{int}})}{2} \qquad (24)$$

where:

$\mathrm{low\_freq}_{\mathrm{int}}$ is the frequency in MHz at the low end of the frequency interval **int**.

$\mathrm{high\_freq}_{\mathrm{int}}$ is the frequency in MHz at the high end of the frequency interval **int**.

int is the index to the frequency interval from $\mathrm{low\_freq}_{\mathrm{int}}$ to $\mathrm{high\_freq}_{\mathrm{int}}$.

The average margin of the PS AXtalk of wire pair **k** between 10 MHz and 400 MHz is computed per equation (25).

$$\mathrm{PSAXtalk}_{\mathrm{AveMargin,\,k}} = \frac{\sum_{\mathrm{int}} \mathrm{PSAXtalk}_{\mathrm{int,\,k}}}{400 - 10} \qquad (25)$$

where

int is the index to the contiguous, non-overlapping frequency intervals in the 10 MHz to 400 MHz frequency range.

Similarly, the margin of the PS AXtalk of the average of all wire pairs is per equation (26).

$$\mathrm{PSAXtalk}_{\mathrm{Margin,\,avg}}(f) = \mathrm{PSAXtalk}_{\mathrm{avg}}(f) - \mathrm{PSAXtalk}_{\mathrm{lim,\,avg}}(f) \tag{26}$$

The average margin of each measurement frequency interval is computed per equation (27).

$$\mathrm{PSAXtalk}_{\mathrm{int,avg}} = \frac{\left\{\begin{array}{l}\mathrm{PSAXtalk}_{\mathrm{Margin,avg}}(\mathrm{high\_freq}_{\mathrm{int}}) + \\ \mathrm{PSAXtalk}_{\mathrm{Margin,avg}}(\mathrm{low\_freq}_{\mathrm{int}})\end{array}\right\}}{2} \cdot (\mathrm{high\_freq}_{\mathrm{int}} - \mathrm{low\_freq}_{\mathrm{int}}) \tag{27}$$

The average margin of the PS AXtalk of the average of all wire pairs between 10 MHz and 400 MHz is computed using equation (28).

$$\mathrm{PSAXtalk}_{\mathrm{AveMargin,\,avg}} = \frac{\sum_{\mathrm{int}} \mathrm{PSAXtalk}_{\mathrm{int,\,avg}}}{400 - 10} \tag{28}$$

where

int is the index to all contiguous, non-overlapping frequency intervals in the 10 MHz to 400 MHz frequency range.

6.7.5.4 PS AXtalk average margin requirements

The overall PS AXtalk average margin is determined by the minimum of the average PS AXtalk margins of each of the 4 wire pairs, and the average PS AXtalk margin of the average of all wire pairs. The overall minimum PS AXtalk average margin shall be > 0 dB for compliance with alien crosstalk requirements per IEEE802.3 10GBASE-T.