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Liaison report from ISO/IEC JTC 1/SC 25/WG 3 to IEEE 802.3 on topics relating to the link segment specification in IEEE802.3an D3.1

To: IEEE 802.3
From: ISO/IEC JTC 1/SC 25/WG 3 Customer premises cabling
Date: 2006-02-20
Venue: Buenos Aires, Argentine, 2006-02-10

ISO/IEC JTC 1/SC 25/WG 3 kindly asks IEEE 802.3 note the following including the attached annexes which together cover the following topics relating to the link segment specification in IEEE802.3an D3.1.

1) Adoption of terms to be used in cabling standards which are currently under development in ISO/IEC JTC 1/SC 25/WG 3, see Annex 1.

   These terms have been implemented in ISO/IEC TR24750 and in the 1st amendment to the 2nd edition of ISO/IEC 11801.

   Specifically, these terms include:

   a. ACR-N for ACR (the insertion loss of the disturbed link segment is used to compute ACR-N from NEXT and insertion loss)

   b. ACR-F for ELFEXT (the insertion loss of the disturbed link segment is used to compute ACR-F from FEXT and insertion loss)

   In order to avoid confusion in the future, SC 25/WG 3 suggests that IEEE802.3an adopts these terms as well.

2) Computation of PS AACR-F (formerly PS AELFEXT) method from measured AFEXT values, see Annex 2.

   This computation applies to the PS AACR-F specifications for Class E_A and F_A cabling in the 1st amendment to the 2nd edition of ISO/IEC 11801. It specifically applies to unequal length link segments and includes a “normalization” based on insertion losses of disturbed and disturbing link segments.

   SC 25/WG 3 kindly asks that IEEE 802.3 provides SC 25/WG 3 with any comments and confirms that this method will provide IEEE 802.3 with sufficient information on alien FEXT performance. Please confirm that this formulation will assure IEEE802.3 10GBASE-T operation on Class E_A and F_A cabling.

3) Expression of IEEE802.3an alien crosstalk requirements for ISO/IEC TR 24750.

   ISO/IEC TR 24750 draft Technical Report includes a specification of the IEEE 802.3an link segment alien crosstalk requirements. Annex 3 shows an excerpt from IEEE 802.3an amended using the terminology specified in Annex 2. Annex 4 provides the text of Annex 3 with the additional replacement of equations presently used in IEEE 802.3an with equations that SC 25/WG 3 intends to use in order to provide additional detail and clarification.

   SC 25/WG 3 kindly asks that IEEE 802.3 evaluates Annex 3 and Annex 4 and provides SC 25/WG 3 with its observations. IEEE 802.3 may wish not only to use the terminology from Annex 1 but also the equations from Annex 4 in IEEE 802.3an for harmonization purposes.

SC 25/WG 3 is pleased to inform IEEE 802.3 that the secretary of ISO/IEC JTC 1/SC 25 will be forwarding to IEEE 802.3 the updated PDTR 24750 and FPDAM for the Amendment to ISO/IEC 11801, both of which will reflect the significant progress achieved during the recent meeting of SC 25/WG 3. IEEE 802.3 may expect these documents before the end of March 2006.

Please ask the Secretary of SC 25 to provide you with the current text and copying permission in case you need to archive drafts of these documents.

Annex 1 – Definitions per 1st Amendment to 2nd Edition of ISO/IEC 11801 and per ISO/IEC TR 24750

alien (exogenous) crosstalk
signal coupling from pairs of a disturbing channel or part thereof, to a disturbed pair of another channel.

alien (exogenous) near-end crosstalk (*ANEXT*)
signal coupling from pairs of a disturbing channel or part thereof, to a disturbed pair of another channel or part thereof, measured at the near-end.

power sum alien (exogenous) near-end crosstalk (*PS ANEXT*)
a computation of the signal coupling from a pair of a disturbing channel, to a disturbed pair of another channel, measured at the near-end.

attenuation to crosstalk ratio at the near end (*ACR-N*)

a computation of the signal coupling from a disturbing pair, to a disturbed pair of within the same channel, measured at the near-end, and relative to the received signal level in the disturbed pair at the near-end.

power sum attenuation to crosstalk ratio at the near end (*PS ACR-N*)
a computation of the signal coupling from multiple disturbing pairs, to a disturbed pair within a channel, measured at the near-end, and relative to the received signal level in the disturbed pair at the near-end.

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

a computation of the signal coupling of a pair of a disturbing channel, to a disturbed pair in another channel, measured at the near-end, and relative to the received signal level in the disturbed pair at the near-end.

power sum attenuation to alien (exogenous) crosstalk ratio at the near end (*PS AACR-N*)
a computation of the signal coupling from multiple pairs of disturbing channels, to a disturbed pair in another channel, measured at the near-end, and relative to the received signal level in the disturbed pair at the near-end.

alien (exogenous) far-end crosstalk (*AFEXT*)
signal coupling from a pair of a disturbing channel to a disturbed pair of another channel, measured at the far-end.

power sum alien (exogenous) far-end crosstalk (*PS AFEXT*)
a computation of signal coupling from pairs of multiple disturbing channels to a disturbed pair of another channel, measured at the far-end.

attenuation to crosstalk ratio at the near end (*ACR-F*)
a computation of the signal coupling from a disturbing pair, to a disturbed pair within the same channel, measured at the far-end, and relative to the received signal level in the disturbed pair at the far-end.

power sum attenuation to crosstalk ratio at the far end (*PS ACR-F*)
a computation of signal coupling from multiple disturbing pairs, to a disturbed pair within the same channel, measured at the far-end, and relative to the received signal level in the disturbed pair at the far-end.

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

a computation of the signal coupling of a pair of disturbing channel, to a disturbed pair in another channel, measured at the far-end, and relative to the received signal level in the disturbed pair at the far-end

power sum attenuation to alien (exogenous) crosstalk ratio at the far end (*PS AACR-F*)
a computation of signal coupling from multiple pairs of disturbing channels, to a disturbed pair in another channel, measured at the far-end, and relative to the received signal level in the disturbed pair at the far-end.

equal level far-end crosstalk (*EL FEXT*)
a computation of the signal coupling from a disturbing pair, to a disturbed pair of within the same channel, measured at the far-end, and relative to the received signal level in the disturbing pair at the far-end (equivalent to the ratio of the signal level in the disturbing pair to the signal coupling in the disturbed pair, hence output-to-output FEXT which is on an equal level along the transmission lines).

power sum equal level far-end crosstalk (*PS ELFEXT*)
a computation of the signal coupling from multiple disturbing pairs, to a disturbed pair within the same channel, measured at the far-end, and relative to the received signal level in each disturbing pair at the far-end.

Normalized alien FEXT ($AFEXT_{norm}$)
Alien far end crosstalk adjusted so that the signal of the disturbing pair is attenuated to the same length as the disturbed pair.

Average PS ANEXT ($PS\ ANEXT_{avg}$)
The average *PS ANEXT* of all pairs in the same channel, expressed in dB.

Average PS AACR-F ($PS\ AACR\text{-}F_{avg}$)
The average *PS AACR-F* of all pairs in the same channel, expressed in dB.

Annex 2 - Computation of PS AACR-F from PS AFEXT and Insertion Loss measurements

These computations address evaluation of Class E_A and F_A cabling. They are intended to be application independent, and implicitly guarantee IEEE802.3an transmission requirements. Specifically, these computations address links which have unequal length/insertion loss properties. In cases where the lengths/insertion loss values are equal, there is no “normalization” as shown in the following, and computations of *PS AACR-F* from *PS AFEXT* and insertion loss values are straightforward. This annex specifies how SC 25/WG 3 calculates PS AACR-F.

Figure 1. shows a disturbing channel j with a pair i that is affecting pair k of a disturbed channel. The Alien FEXT coupling is shown as $AFEXT_{k,i,j}$.

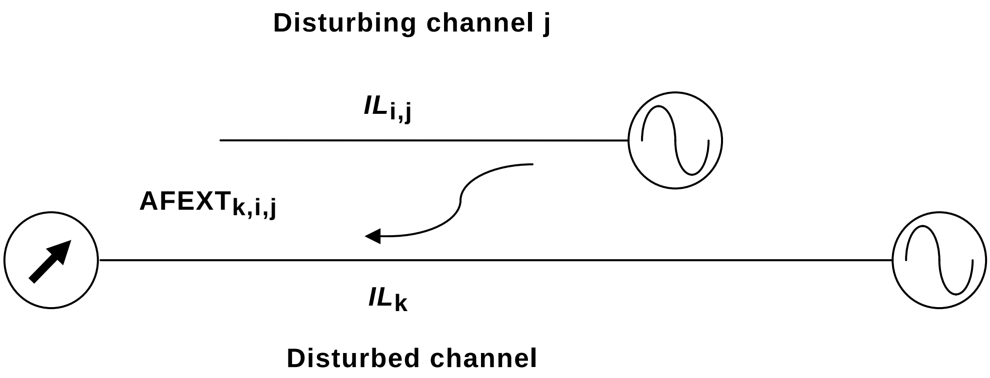

Figure 1: Schematic diagram of AFEXT coupling.

ISO/IEC 11801 uses the following computation for Class E_A and F_A cabling.

The *PS AACR-F* is computed as follows from the pair-to-pair *FEXT* measurements, and insertion losses of disturbing and disturbed channels.

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 as in equation (1).

If $IL_{k} - IL_{i,j} > 0$ then:

$$AFEXTnorm_{k,i,j} = AFEXT_{k,i,j} + IL_{k} - IL_{i,j} \qquad (1)$$

Otherwise:

$$AFEXTnorm_{k,i,j} = AFEXT_{k,i,j} \qquad (2)$$

where:

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

$AFEXT_{k,i,j}$ is 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_{k} is the measured insertion loss in dB of wire pair k of the disturbed channel.

$IL_{i,j}$ is the measured insertion loss in dB of wire pair i of disturbing channel j.

The power sum alien *FEXT* of pair k $PS\ AFEXT_{k}$ of a disturbed channel is computed per equation (2).

$$PS\ AFEXT_{k} = -10\lg\left(\sum_{j=1}^{N}\sum_{i=1}^{n}10^{\frac{-\left(AFEXTnorm_{k,i,j}\right)}{10}}\right) \qquad (2)$$

where:

n is the number of wire pairs in disturbing channel j

N is the total number if disturbing channels.

The $PS\ AACR\_F_{k}$ of pair k of a disturbed channel is computed per equation (3).

$$PS\ AACR\_F_{k} = PS\ AFEXT_{k} - IL_{k} \qquad (3)$$

Annex 3 - IEEE 802.3an link segment specification with SC 25 terminology

5.1 Alien (Exogenous) crosstalk

5.1.1 General

Power-Sum Alien NEXT (*PS ANEXT*) and Power-Sum Alien attenuation to crosstalk ratio far end (*PS AACR-F*) are specified in the following clause, in accordance with 10GBASE-T.

NOTE Formulae used in 5.1.2 and 5.1.3 for alien crosstalk limits are numerically different to those currently used by IEEE 802.3an; however they are technically equivalent, more concise and better suited for a cabling document.

For a detail description of how to proceed for compliance in case some limits of alien noise are not met see clause 5.1.4.

5.1.2 Power Sum alien NEXT (PSANEXT)

The following limits shall be met (see also clause 4).

- One limit to be met by all pairs
- Another limit of +2,25 dB for the average of the four pairs in the channel. Average *PS ANEXT* is calculated by averaging the individual *PS ANEXT* calculations in decibels at each frequency point. The average applies to all pairs of the disturbed channel.

The allowable *PS ANEXT* is inter-related to the insertion loss of the channel and is based upon the calculated or measured insertion loss at 250 MHz as detailed below.

To support 10GBASE-T the *PS ANEXT* for each pair in a channel shall meet the limits computed, to one decimal place, using the formulae Table 1. The limits shown in Table 2 are derived from the formulae at key frequencies.

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

PS A*NEXT*$_k$ of pair *k* is computed as follows:

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

where

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

NOTE Pairs external to the channel are all those pairs surrounding the channel that belong to other channels and that could disturb each pair in the channel (ffs)

The average *PS ANEXT* of all wire pairs is computed by averaging the values of each wire pair expressed in dB as in equation (2).

$$PS\ ANEXT_{avg} = \frac{1}{4}\sum_{k=1}^{4} PS\ ANEXT_k \qquad \textbf{(2)}$$

Table 1- Formulae for PS ANEXT limits for a channel

Frequency MHz	**Minimum PS ANEXT** dB	
$1 \le f \le 100$	$27{,}48 + IL(250)/1{,}04 - 10\lg(f/100)$	For every pair
$100 < f \le 500$	$27{,}48 + IL(250)/1{,}04 - 15\lg(f/100)$	
$1 \le f \le 100$	$29{,}73 + IL(250)/1{,}04 - 10\lg(f/100)$	For the average of the 4 pairs per disturbed channel
$100 < f \le 500$	$29{,}73 + IL(250)/1{,}04 - 15\lg(f/100)$	
Where *IL*(250) is channel insertion loss at 250 MHz in dB rounded to one decimal place *IL*(250) values less then 6,3 dB revert to a value of 6,3 dB 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.		

Table 2 – PS ANEXT limits for a channel at key frequencies

	Minimum PS ANEXT dB					
Frequency (MHz)	**1,0**	**16,0**	**100,0**	**250,0**	**500,0**	
IL(250) = 20,3 dB	67,0	55,0	**47,0**	41,0	36,5	For every pair
IL(250) = 33,8 dB	67,0	67,9	**60,0**	54,0	49,5	
IL(250) = 35,9 dB	67,0	70,0	**62,0**	56,0	51,5	
IL(250) = 20,3 dB	67,0	57,25	49,25	43,25	38,75	For the average of the 4 pairs per disturbed channel
IL(250) = 33,8 dB	67,0	67,0	62,25	55,25	51,75	
IL(250) = 35,9 dB	67,0	67,0	64,25	58,25	53,75	
NOTE The IEEE 802.3an *PSNEXT* constants are shown in bold						

Values of *PS ANEXT* at frequencies for which the measured channel insertion loss is below 4,0 dB are for information only.

5.1.3 Power sum alien attenuation to crosstalk ratio far end (PS AACR-F)

To support 10GBASE-T the following limits shall be met (see also clause 4).

- One limit to be met by all pairs

- Another limit of +4 dB for the average of the four pairs in the channel. Average *PS AACR-F* is calculated by averaging the individual PS AACR-F calculations in decibels at each frequency point. The average applies to all pairs of the disturbed channel.

The *PS AACR-F* for each pair combination of a channel shall meet the limits computed, to one decimal place, using the formulae of Table 3. The limits shown in Table 4 are derived from the formulae at key frequencies.

PS $AFEXT_k$ of pair *k* is computed as follows:

$$PS\,AFEXT_k = -10\lg\left[\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{\frac{-AFEXT_{l,i,k}}{10}}\right] \qquad \textbf{(3)}$$

where

k	is the number of the disturbed pair in the disturbed channel;
i	is the counter of the disturbing pairs in the disturbing channel l;
l	is the summing counter of the disturbing channels;
N	is the number of disturbing channels
n	is the number of disturbing pairs in each of the N channels;
$AFEXT_{l,i,k}$	is the alien far end crosstalk loss coupled from pairs i of channel l to the pair k.

PS $AACR\text{-}F_k$ of pair k is computed as follows:

$$PS\,AACR - F_k = PS\,AFEXT_k - IL_{avg} \qquad \textbf{(4)}$$

where

i	is the counter of the disturbing pair;
k	is the counter of the disturbed pair;
ILavg	is the average insertion loss of all 4 pairs of the disturbed channel in dB. When required, it shall be measured according to IEC 61935-1 and calculated per equation (11).

$$IL_{avg} = \frac{1}{4}\sum_{k=1}^{4} IL_k \qquad \textbf{(5)}$$

NOTE Pairs external to the channel are all those pairs surrounding the channel that belong to other channels and that could disturb each pair in the channel (ffs).

The average *PS AFEXT* of all wire pairs is computed by averaging the values of each wire pair expressed in dB as in equation (6).

$$PS\,AFEXT_{\text{avg}} = \frac{1}{4}\sum_{\text{k}=1}^{4} PS\,AFEXT_{\text{k}}$$

(6)

The $PS\,AACR\_F_{\text{avg}}$ is computed per equation (7).

$$PS\,AACR\_F_{\text{avg}} = PS\,AFEXT_{\text{avg}} - IL_{\text{avg}} \qquad \textbf{(7)}$$

Table 3- Formulae for PS AACR-F limits for a channel

Frequency **MHz**	**Minimum PS AACR-F** dB	
1 ≤ f ≤ 500	$22{,}22 + IL(250)/2{,}29 - 20\lg(f/100) - 10\lg(L/100)$	For every pair
1 ≤ f ≤ 500	$26{,}22 + IL(250)/2{,}29 - 20\lg(f/100) - 10\lg(L/100)$	For the average of the 4 pairs per disturbed channel
Where *IL*(250) is channel insertion loss at 250 MHz in dB to one decimal place, *L* is physical channel length in m *IL*(250) values less then 10,0 dB shall revert to a value of 10,0 dB; *L* reverts to 2,77 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 4 - PS AACR-F limits for a channel at key frequencies and lengths

	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	67,0	49,6	**33,7**	25,7	19,7	For every pair
IL(250) = 33,8 dB; *L*=100m	67,0	52,9	**37,0**	29,0	23,0	
IL(250) = 35,9 dB; *L*=100m	67,0	53,8	**37,9**	29,9	23,9	
IL(250) = 20,3 dB; *L*=55m	67,0	53,6	37,7	29,7	23,7	For the average of the 4 pairs per disturbed channel
IL(250) = 33,8 dB; *L*=100m	67,0	56,9	41,0	33.0	27,0	
IL(250) = 35,9 dB; *L*=100m	67,0	57,6	41,9	33,7	27,7	
Note: The IEEE 802.3an constants are shown in bold						

5.1.4 Alien crosstalk margin computation

5.1.4.1 General

Editors note: This clause is a one to one transcription from IEEE 802.3 an Draft 3.0 chapter 55.7.3.3. Only the references and the equation numbers were adapted fit to ISO/IEC 24750, and the necessary backoff Table 19 copied.

The objective of alien crosstalk margin computation is to further characterise the alien crosstalk coupling . The alien crosstalk margin computation ensures the total combined *PS AFEXT* and *PS ANEXT* coupled into a duplex channel is limited in order to maintain the minimum signal to noise ratio. The alien crosstalk margin computation can be applied in the event that the *PS ANEXT* limits specified in clause (5.1.2) or the *PS ACR-F* limits specified in clause (5.1.3) are not met. The alien crosstalk margin is specified for each of the individual 4-pairs as well as the average "across the 4-pairs".

5.1.4.2 The alien crosstalk margin is determined by the following algorithm:

Step 1: Determine the length of the disturbed link segment and the disturbing link segments using equation (8)

$$L = 2{,}77\ IL\_avg \qquad (8)$$

Where:

IL_avg is the average measured insertion loss at 250 MHz “across the 4-pairs” of each disturbed and disturbing link segment.

L is the length in meters for each disturbed and disturbing link segment derived from the measured insertion loss.

Step 2: Determine the minimum power backoff (dB) for each disturbed and disturbing link segment from Table 5 Power backoff schedule from main body IEEE Draft 2.4 Power backoff schedule utilising the calculated link segment length from step 1. (e.g., from Table 5; a length of 30 m has a minimum power backoff of 10 dB).

Table 5 Power backoff schedule from main body IEEE Draft 2.4

Received signal power at MDI on worst pair dBm	**Reference length** m	**Minimum power backoff** dB
>0,3	0 to ≤25	10
-1,1 to 0,3	>25 to ≤35	10
-2,3 to -1,1	>35 to ≤45	8
-3,3 to -2,3	>45 to ≤55	6
-4,2 to -3,3	>55 to ≤65	4
-5,0 to -4,2	>65 to ≤75	2
-5,7 to -5,0	>75 to ≤85	0
<= -5,7	>85	0

Editors Note: ≤ and > signs have been added to column 2 in order to avoid ambiguities. IEEE 802.3 is kindly asked to confirm.

Step 3: Determine the insertion loss backoff factor using equation (9)

$$IL\_bof_j = \min\_PBO\_\text{disturbing link}_j - \min\_PBO\_\text{disturbed link} \qquad \textbf{(9)}$$

Where:

*IL*_bof$_j$ is calculated as the difference between the minimum power backoff (dB) of the disturbing link *j* and the disturbed link segments determined in Step 2.

*PBO*_disturbing link$_j$ Is the power back off applicable to the disturbing link j

*PBO*_disturbed link is the power back of applicable to the disturbed link

Step 4: Determine the *PS ANEXT* and the *PS AFEXT* from the measured *ANEXT* and *AFEXT* and the insertion loss backoff factor for each disturbed pair *N*=1,2,3,4 of a link segment using equation (10) and equation (11) respectively.

$$PS\ ANEXT_N(f) = -10 \times \log_{10} \sum_{j=1}^{m} \sum_{i=1}^{4} 10^{\frac{-(AN\_pr(f)_{i,j,N} + IL\_bof_j)}{10}} \text{ dB} \qquad \textbf{(10)}$$

$$PS\ AFEXT_N(f) = -10 \times \log_{10} \sum_{j=1}^{m} \sum_{i=1}^{4} 10^{\frac{-(AF\_pr(f)_{i,j,N} + IL\_bof_j)}{10}} \text{ dB} \qquad \textbf{(11)}$$

Where:

$AN\_pr(f)_{i,j,N}$	is the measured ANEXT of the individual pair combination (1 to 4) of the disturbing link (1 to m) for each disturbed pair N.
$AF\_pr(f)_{i,j,N}$	is the measured AFEXT of the individual pair combination (1 to 4) of the disturbing link (1 to m) for each disturbed pair N.
IL_bof_j	is the insertion loss backoff factor determined in equation (9)

Editors note: the terms and indices used in equations (10, 11, 12, 15 and 17) need to be aligned with those in equations (1 and 2)

Step 5: Determine the individual-pair margin for each of the 4-pairs using equation (12).

$$XWn(f) = -10 \times \log 10\left(10^{\frac{AN(f)}{-10}} + 10^{\frac{AF(f)}{-10}}\right) + 10 \times \log 10\left(10^{\frac{AN\_ipl(f) + 2.5}{-10}} + 10^{\frac{AF\_ipl(f)}{-10}}\right) \quad (dB) \qquad (12)$$

Where:

f	is the frequency in MHz
$XWn(f)$	is the individual-pair margin for each of the 4-pairs
$AN(f)$	is the measured *PS ANEXT* Loss in dB in the frequency range ($10 \le f \le 400$) MHz determined in equation (10) adjusted for the insertion loss power backoff.
$AF(f)$	is the measured *PS AFEXT* Loss in dB in the frequency range ($10 \le f \le 400$) MHz determined in equation (11) adjusted for the insertion loss power backoff.
$AN\_ipl(f)$	is the individual-pair limit line for *PS ANEXT* as specified in clause (5.1.2) utilizing the measured insertion loss of the individual-pair.
$AF\_ipl(f)$	is the individual-pair limit line for *PS AFEXT* calculated from the *PS AELFEXT* equation specified in clause(5.1.3) utilizing the measured insertion loss of the individual-pair.

Note: The 2,5 dB is the *PS ANEXT* allowance for the peak-to-average difference across frequency

Step 6: Determine the average value "across frequency" of XWn(f) from 10 MHz to 400 MHz, for each individual-pair of the 4-pair cabling using equation (13).

$$XAWn = \frac{\int_{f=10}^{400} XWn(f)df}{390} \quad (dB)$$

(13)

Where:

F	is the frequency in MHz
XAWn	is the average value “across frequency” for the individual-pair number n (n=1,2,3,4)

Step 7: Determine the individual-pair margin as the minimum of the average value "across frequency" of each of the individual pairs of the 4-pair cabling determined from step 2 using equation (14).

$$Y_{inp} = \min(XAW1, XAW2, XAW3, XAW4) \quad (dB)$$

(14)

Where:

Y_{inp}	is the the individual-pair margin
XAWn	is the average value “across frequency” for the individual-pair number n (n=1,2,3,4)

Step 8: Determine the power sum of the *PS ANEXT* and *PS AFEXT* for each of the 4-pairs using equation (15).

$$XXn(f) = 10 \times \log 10\left(10^{\frac{AN(f)}{-10}} + 10^{\frac{AF(f)}{-10}}\right) \quad (dB)$$

(15)

Where:

f is the frequency in MHz

XXn(f) is the power sum of the *PS ANEXT* and *PS AFEXT* for each of the 4-pairs

AN(f) is the measured *PS ANEXT* Loss in dB in the frequency range (10≤ *f* ≤ 400) MHZ determined in equation (10) adjusted for the insertion loss power backoff.

AF(f) is the measured *PS AFEXT* Loss in dB in the frequency range (10≤ *f* ≤ 400) MHz determined in equation (11) adjusted for the insertion loss power backoff.

Step 9: Determine the average of the power sum of the *PS ANEXT* and *PS AFEXT* of the 4-pairs using equation (16).

$$XXavg(f) = \frac{\left(\sum_{i=1}^{n} XXi(f)\right)}{4} \quad (dB)$$

(16)

Where:

*XX*avg(f) is the average of the power sum of the *PS ANEXT* and *PS AFEXT* of the 4-pairs

*XX*i is the power sum of the *PS ANEXT* and *PS AFEXT* for pairs i

n is the number of individual pairs; n = 4

Step 10: Determine the average margin using equation (17).

$$XA(f) = -XXavg + 10 \times \log 10\left(10^{\frac{AN\_avgl(f)}{-10}} + 10^{\frac{AF\_avgl(f)}{-10}}\right) \quad (dB)$$

(17)

Where:

XA(f) is the average margin.

XXavg is the average of the power sum of the *PS ANEXT* and *PS AFEXT* of the 4-pairs

AN_avgl(f) is the average limit line for *PS ANEXT* as calculated using equation (18).

AN_avgl(f) is derived using the *PS ANEXT* constant that is the minimum of the individual-pair *PS ANEXT* constants.

$$AN\_avgl(f) = \left(\min\left(PS\ \ ANEXTconstant\right) + 3{,}5\right) - 10\lg\left(\frac{f}{100}\right)$$ (dB) 1≤ *f* ≤ 100

$$AN\_avgl(f) = \left(\min\left(PS\ \ ANEXTconstant\right) + 3{,}5\right) - 20\lg\left(\frac{f}{100}\right)$$ (dB) 100< *f* ≤ 500

(18)

where

f is the frequency in MHz.

AF_avgl(f) is the average limit line for *PS AFEXT* calculated using equation 19).

AF_avgl(f) is derived by adding the measured IL from the pair with the minimum *PS AELFEXT* constant to the *PS AELFEXT* limit line using the *PS AELFEXT* constant that is the minimum of the individual-pair *PS AELFEXT*.

$$AF\_avgl(f) = \left(\min\left(PS\ AACR - Fconstant\right) + 4\right) - 20\lg\left(\frac{f}{100}\right) + ILmin\left(f\right) \qquad (dB)$$

1≤ *f* ≤ 500 19)

Step 11: Determine the average margin as the average value across frequency of *XA(f)* using equation (20).

$$Y_{avg} = \frac{\int_{f=10}^{400} XA(f)df}{390} \qquad (dB) \qquad \textbf{(20)}$$

Where:

f is the frequency in MHz

XA is the average margin

Y_{avg} is the average value "across frequency" of *XA(f)* from 10 MHz to 400 MHz

Step 12: Determine the alien crosstalk margin as the minimum value of the individual pair margin (equation (14)) and the average margin (equation (17)) using equation (21).

$$YL = min(Y_{\text{inp}}, Y_{\text{avg}}) \qquad (dB) \qquad \textbf{(21)}$$

The alien crosstalk margin *YL* shall be greater than zero.

5.1.5 Examples of implementations at key IL(250)

Table 4 provides examples of channel lengths that will support 10GBASE-T in reliance on the minimum performance of class E and class F as specified in ISO/IEC 11801:2002 and the noise levels specified in 5.1.2and 5.1.3

Table 6- Examples of implementations at key insertion loss

Channel length m	**Class**	**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]	E	42,8 + 10	47	33,7
55 [a]	F	45,8 + 10		
***IL* at 250 MHz = 33,8 dB**				
100 [a]	E	83,5 + 10	60	37
100 [a]	F	90 + 10		
***IL* at 250 MHz = 35,9 dB**				
100 [a]	E	90 + 10	62	37,9
100 [a]	F	90 + 10		
[a] not exactly 55 m and 100 m respectively but formulae not so length sensitive				

Annex 4 - IEEE 802.3an link segment specification with SC 25 terminology and equations proposed by SC 25/WG 3

5.1 Alien (Exogenous) crosstalk

5.1.1 General

Power-Sum Alien NEXT (*PS ANEXT*) and Power-Sum Alien attenuation to crosstalk ratio far end (*PS AACR-F*) are specified in the following clause, in accordance with 10GBASE-T.

NOTE Formulae used in 5.1.2 and 5.1.3 for alien crosstalk limits are numerically different to those currently used by IEEE 802.3an; however they are technically equivalent, more concise and better suited for a cabling document.

For a detail description of how to proceed for compliance in case some limits of alien noise are not met see clause 5.1.4.

5.1.2 Power Sum alien NEXT (PSANEXT)

The following limits shall be met:

- One limit to be met by all pairs
- Another limit of +2,25 dB for the average of the four pairs in the channel. Average *PS ANEXT* is calculated by averaging the individual *PS ANEXT* calculations in decibels at each frequency point. The average applies to all pairs of the disturbed channel.

The allowable *PS ANEXT* is inter-related to the insertion loss of the channel and is based upon the calculated or measured insertion loss at 250 MHz as detailed below.

To support 10GBASE-T the *PS ANEXT* for each pair in a channel shall meet the limits computed, to one decimal place, using the formulae Table 1. The limits shown in Table 2 are derived from the formulae at key frequencies.

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

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

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

where

k	is the number of the disturbed pair in the disturbed channel;
i	is the counter of the disturbing pairs in the disturbing channel *l*;
l	is the summing counter of the disturbing channels;
N	is the number of disturbing channels
n	is the number of disturbing pairs in each of the *N* channels;
$ANEXT_{l,i,k}$	is the alien near end crosstalk loss coupled from pairs *i* of disturbing channel *l* to the disturbed pair *k*.

NOTE Pairs external to the channel are all those pairs surrounding the channel that belong to other channels and that could disturb each pair in the channel (ffs)

The average *PS ANEXT* of all wire pairs is computed by averaging the values of each wire pair expressed in dB as in equation(2).

$$PS\ ANEXT_{avg} = \frac{1}{4}\sum_{k=1}^{4} PS\ ANEXT_{k} \qquad \textbf{(2)}$$

Table 1- Formulae for PS ANEXT limits for a channel

Frequency MHz	**Minimum PS ANEXT** dB	
$1 \le f \le 100$	$27{,}48 + IL(250)/1{,}04 - 10\lg(f/100)$	For every pair
$100 < f \le 500$	$27{,}48 + IL(250)/1{,}04 - 15\lg(f/100)$	
$1 \le f \le 100$	$29{,}73 + IL(250)/1{,}04 - 10\lg(f/100)$	For the average of the 4 pairs per disturbed channel
$100 < f \le 500$	$29{,}73 + IL(250)/1{,}04 - 15\lg(f/100)$	
Where *IL*(250) is channel insertion loss at 250 MHz in dB rounded to one decimal place *IL*(250) values less then 6,3 dB revert to a value of 6,3 dB 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.		

Table 2 – PS ANEXT limits for a channel at key frequencies

	Minimum PS ANEXT dB					
Frequency (MHz)	**1,0**	**16,0**	**100,0**	**250,0**	**500,0**	
IL(250) = 20,3 dB	67,0	55,0	**47,0**	41,0	36,5	For every pair
IL(250) = 33,8 dB	67,0	67,9	**60,0**	54,0	49,5	
IL(250) = 35,9 dB	67,0	70,0	**62,0**	56,0	51,5	
IL(250) = 20,3 dB	67,0	57,25	49,25	43,25	38,75	For the average of the 4 pairs per disturbed channel
IL(250) = 33,8 dB	67,0	67,0	62,25	55,25	51,75	
IL(250) = 35,9 dB	67,0	67,0	64,25	58,25	53,75	
NOTE The IEEE 802.3an *PSNEXT* constants are shown in bold.						

Values of *PS ANEXT* at frequencies for which the measured channel insertion loss is below 4,0 dB are for information only.

5.1.3 Power sum alien attenuation to crosstalk ratio far end (PS AACR-F)

To support 10GBASE-T the following limits shall be met.

- One limit to be met by all pairs
- Another limit of +4 dB for the average of the four pairs in the channel. Average *PS AACR-F* is calculated by averaging the individual PS AACR-F calculations in decibels at each frequency point. The average applies to all pairs of the disturbed channel.

The *PS AACR-F* for each pair combination of a channel shall meet the limits computed, to one decimal place, using the formulae of Table 3. The limits shown in Table 4 are derived from the formulae at key frequencies.

$PS\ AFEXT_k$ of pair *k* is computed as follows:

$$PS\ AFEXT_k = -10\ \lg \left[\sum_{l=1}^{N} \sum_{i=1}^{n} 10^{\frac{-AFEXT_{l,i,k}}{10}} \right] \quad \textbf{(3)}$$

where

k	is the number of the disturbed pair in the disturbed channel;
i	is the counter of the disturbing pairs in the disturbing channel *l*;
l	is the summing counter of the disturbing channels;
N	is the number of disturbing channels
n	is the number of disturbing pairs in each of the *N* channels;
$AFEXT_{l,i,k}$	is the alien far end crosstalk loss coupled from pairs *i* of channel *l* to the pair *k*.

$PS\ AACR\text{-}F_k$ of pair *k* is computed as follows:

$$PS\ AACR - F_k = PS\ AFEXT_k - IL_{avg} \quad \textbf{(4)}$$

where

i	is the counter of the disturbing pair;
k	is the counter of the disturbed pair;
IL_{avg}	is the average insertion loss of all 4 pairs of the disturbed channel in dB. When required, it shall be measured according to IEC 61935-1 and calculated per equation (5).

$$IL_{avg} = \frac{1}{4} \sum_{k=1}^{4} IL_k \quad \textbf{(5)}$$

NOTE Pairs external to the channel are all those pairs surrounding the channel that belong to other channels and that could disturb each pair in the channel (ffs).

The average *PS AFEXT* of all wire pairs is computed by averaging the values of each wire pair expressed in dB as in equation (6).

$$PS\ AFEXT_{\mathrm{avg}} = \frac{1}{4} \sum_{\mathrm{k}=1}^{4} PS\ AFEXT_{\mathrm{k}}$$

(6)

The $PS\ AACR\_F_{\mathrm{avg}}$ is computed per equation (7).

$$PS\ AACR\_F_{\mathrm{avg}} = PS\ AFEXT_{\mathrm{avg}} - IL_{\mathrm{avg}} \quad \textbf{(7)}$$

Table 3- Formulae for PS AACR-F limits for a channel

Frequency MHz	**Minimum PS AACR-F** dB	
$1 \leq f \leq 500$	$22{,}22 + IL(250)/2{,}29 - 20\lg(f/100) - 10\lg(L/100)$	For every pair
$1 \leq f \leq 500$	$26{,}22 + IL(250)/2{,}29 - 20\lg(f/100) - 10\lg(L/100)$	For the average of the 4 pairs per disturbed channel
Where *IL*(250) is channel insertion loss at 250 MHz in dB to one decimal place, *L* is physical channel length in m *IL*(250) values less then 10,0 dB shall revert to a value of 10,0 dB; *L* reverts to 2,77 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 4 - PS AACR-F limits for a channel at key frequencies and lengths

	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*=100m	64,8	52,9	**37,0**	29,0	12,2	
IL(250) = 35,9 dB; *L*=100m	64,7	53,8	**37,9**	29,9	8,1	
IL(250) = 20,3 dB; *L*=55m	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*=100m	64,8	56,9	41,0	33.0	12,2	
IL(250) = 35,9 dB; *L*=100m	64,7	57,6	41,9	33,7	8,1	
Note: The IEEE 802.3AN constants are shown in bold.						

5.1.4 Alien crosstalk margin computation

5.1.4.1 General

Editors note: This clause is a one to one transcription from IEEE 802.3 an Draft 3.0 chapter 55.7.3.3. Only the references and the equation numbers were adapted accordingly, and the necessary backoff Table 19 copied into.

The objective of alien crosstalk margin computation is to further characterise the alien crosstalk coupling. The alien crosstalk margin computation ensures the total combined *PS AFEXT* and *PS ANEXT* coupled into a duplex channel is limited in order to maintain the minimum signal to noise ratio. The alien crosstalk margin computation can be applied in the event that the *PS ANEXT* limits specified in clause (5.1.2) or the *PS AACR-F* limits specified in clause (5.1.3) are not met. The alien crosstalk margin is specified for each of the individual 4-pairs as well as the average "across the 4-pairs".

5.1.4.2 The alien crosstalk margin is determined by the following algorithm:

Determine the length of the disturbed channel and the disturbing channel using equation (8)

$$L=2{,}77\ IL\_avg \qquad (8)$$

Where:

*IL*_avg is the average measured insertion loss at 250 MHz “across the 4-pairs” of each disturbed and disturbing channel.

L is the length in meters for each disturbed and disturbing channel segment derived from the measured insertion loss.

Determine the minimum power backoff (dB) for each disturbed and disturbing channel from Table 5 Power backoff schedule from main body IEEE802.3 10GBASE-T. Power backoff schedule utilising the calculated channel length from equation 8. (e.g., from Table 5; a length of 30 m has a minimum power backoff of 10 dB).

Table 5 Power backoff schedule from main body IEEE802.3 10GBASE-T.

Received signal power) at MDI on worst pair dBm	**Reference length** m	**Minimum power backoff** dB
>0,3	0 to ≤25	10
-1,1 to 0,3	>25 to ≤35	10
-2,3 to -1,1	>35 to ≤45	8
-3,3 to -2,3	>45 to ≤55	6
-4,2 to -3,3	>55 to ≤65	4
-5,0 to -4,2	>65 to ≤75	2
-5,7 to -5,0	>75 to ≤85	0
<= -5,7	>85	0

Editors Note: ≤ and > signs have been added to column 2 in order to avoid ambiguities. IEEE 802.3 is kindly asked to confirm.

Determine the insertion loss backoff factor using equation (9)

$$IL\_bof_l = min\_PBO\ disturbing\_link_l - min\_PBO\ disturbed\_link \qquad \textbf{(9)}$$

Where:

IL_bof_l is calculated as the difference between the minimum power backoff (dB) of the disturbing channel j and the disturbed channels.

*PBO*_disturbing link$_j$ Is the power back off applicable to the disturbing link j

*PBO*_disturbed link is the power back of applicable to the disturbed link

Determine the *PS ANEXT_bof* and the *PS AFEXT_bof* from the measured *ANEXT* and *AFEXT* and the insertion loss backoff factor for each disturbed pair *k*=1,2,3,4 of a channel using equation (10) and equation (11) respectively.

$$PS\ ANEXT\_bof_k = -10\lg\left[\sum_{l=1}^{N}\sum_{i=1}^{n}10^{\frac{-\left(ANEXT_{l,i,k}+IL\_bof_l\right)}{10}}\right]\textbf{dB} \qquad \textbf{(10)}$$

$$PS\ AFEXT\_bof_k = -10\lg\left[\sum_{l=1}^{N}\sum_{i=1}^{n}10^{\frac{-\left(AFEXT_{l,i,k}+IL\_bof_l\right)}{10}}\right]\text{dB} \qquad \textbf{(11)}$$

Where:

$ANEXT_{l,i,k}$ is the measured ANEXT of the individual pair combination l (1 to 4) of the disturbing channel (1 to n) for each disturbed pair k;

$FNEXT_{l,i,k}$ is the measured AFEXT of the individual pair combination l (1 to 4) of the disturbing channel (1 to n) for each disturbed pair k;

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

i is the counter of the disturbing pairs in the disturbing channel *l*;

l	is the summing counter of the disturbing channels;
N	is the number of disturbing channels
n	is the number of disturbing pairs in each of the *N* channels, n = 4;
IL_bof_l	is the insertion loss backoff factor determined in equation (9)

The total alien crosstalk $PS\,AXtalk_k$ of each individual pair k is computed per equation (12)

$$PS\,AXtalk_k = -10\lg\left[10^{\frac{-PS\,ANEXT\_bof_k}{10}} + 10^{\frac{-PS\,AFEXT\_bof_k}{10}}\right]\text{dB} \qquad (12)$$

Compute the individual pair margin limit using equation (13).

$$PS\,AXtalk\_limit_k = -10\lg\left[10^{\frac{-\left(PS\,ANEXT\_limit_k + 2.5\right)}{10}} + 10^{\frac{-\left(PS\,AACR-F\_limit_k + IL_{avg}\right)}{10}}\right] \qquad (13)$$

where:

$PS\,ANEXT\_limit_k$	is the minimum PS ANEXT for any pair in a channel per Table 1.
$PS\,AACR-F\_limit$	is the minimum PS AACR-F for any pair in a channel per Table 3.
IL_{avg}	is the average insertion loss across the 4-pairs.

Note: The 2,5 dB is the *PS ANEXT* allowance for the peak-to-average difference across frequency

Determine the individual-pair margin for each of the 4-pairs using equation 14.

$$PS\,AXtalk\_margin_k = PS\,AXtalk_k - PS\,AXtalk\_limit_k \qquad (14)$$

The average individual pair margin for each frequency interval m with upper frequency $f_{high,m}$ and lower frequency $f_{low,m}$ is given by equation (15).

$$PS\,AXtalk\_AVGmargin_{k,m} = PS\,AXtalk\_margin_k\left(f_{high,m}\right) - PS\,AXtalk\_margin_k\left(f_{low,m}\right)\frac{f_{high,m} - f_{low,m}}{2} \qquad (15)$$

The average value “across frequency” is from 10 MHz to 400 MHz, for each individual-pair of the 4-pair cabling is computed summing all average margins in each frequency interval in the 10 MHz to 400 MHz frequency range using equation (16).

$$PS\,AXtalk\_AVGmargin_k = \frac{\sum_m PS\,AXtalk\_AVGmargin_{k,m}}{390} \qquad (16)$$

The minimum average margins of all pairs is given by equation (17).

$$PS\,AXtalk\_AVGmargin_{pair} = \min\begin{pmatrix} PS\,AXtalk\_AVGmargin_1, PS\,AXtalk\_AVGmargin_2, \\ PS\,AXtalk\_AVGmargin_3, PS\,AXtalk\_AVGmargin_4 \end{pmatrix} \text{dB} \quad (17)$$

Where:

$PS\,AXtalk\_AVGmargin_{pair}$ is the individual-pair average alien crosstalk margin

Determine the average of the power sum of the *PS ANEXT* and *PS AFEXT* of the 4-pairs using equation (18).

$$PS\,AXtalk_{avg} = \frac{\sum_{k=1}^{4} PS\,AXtalk_k}{4}$$

(18)

Compute the average margin limit using equation (19).

$$PS\,AXtalk\_limit_{avg} = -10\,\lg\left[10^{\frac{-\left(PS\,ANEXT\_limit_k + 3.5\right)}{10}} + 10^{\frac{-\left(PS\,AACR-F\_limit_k + IL_{avg} + 4\right)}{10}}\right]$$

(19)

where:

$PS\,ANEXT\_limit_k$ is the minimum PS ANEXT for any pair in a channel per Table 1.

$PS\,AACR-F\_limit$ is the minimum PS AACR-F for any pair in a channel per Table 3.

IL_{avg} is the average insertion loss across the 4-pairs.

Note: The 3,5 dB is the *PS ANEXT* allowance for the peak-to-average difference across frequency and averaged over 4 pairs.

The average all pairs margin for each frequency interval m with upper frequency $f_{high,m}$ and lower frequency $f_{low,m}$ is given by equation (20).

$$PS\,AXtalk\_AVGmargin_{avg,m} = PS\,AXtalk\_margin_{avg}\left(f_{high,m}\right) - PS\,AXtalk\_margin_{avg}\left(f_{low,m}\right)\frac{f_{high,m} - f_{low,m}}{2}$$

(20)

The average value “across frequency” is from 10 MHz to 400 MHz, for each individual-pair of the 4-pair cabling is computed summing all average margins in each frequency interval using equation (21).

$$PS\,AXtalk\_AVGmargin_{avg} = \frac{\sum_{m} PS\,AXtalk\_AVGmargin_{avg,m}}{390} \quad (21)$$

Determine the overall alien crosstalk margin as the minimum value of the individual pair margin (from equation **(17)**) and the average margin from equation 21 using equation (22).

$$PS\,AXtalk\_AVGmargin_{overall} = \min\left(PS\,AXtalk\_AVGmargin_{pairs}, PS\,AXtalk\_AVGmargin_{avg}\right) \text{ dB}$$

(22)

The alien crosstalk margin $PS\,AXtalk\_AVGmargin_{overall}$ shall be greater than zero.

5.1.5 Examples of implementations at key IL(250)

Table 4 provides examples of channel lengths that will support 10GBASE-T in reliance on the minimum performance of class E and class F as specified in ISO/IEC 11801:2002 and the noise levels specified in 5.1.2and 5.1.3

Table 6- Examples of implementations at key insertion loss

Channel length m	**Class**	**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]	E	42,8 + 10	47	33,7
55 [a]	F	45,8 + 10		
***IL* at 250 MHz = 33,8 dB**				
100 [a]	E	83,5 + 10	60	37
100 [a]	F	90 + 10		
***IL* at 250 MHz = 35,9 dB**				
100 [a]	E	90 + 10	62	37,9
100 [a]	F	90 + 10		
[a] not exactly 55 m and 100 m respectively but formulae not so length sensitive				