Proposed ALSNR Replacement Text for D2.1

(Contribution to IEEE 802.3bz Task Force in support of comments on the initial working group ballot)

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ABSTRACT:

This contribution provides a clarified and explicit procedure for measurement of ALSNR according to IEEE 802.3bz Draft 2.0.

Detailed analysis of this proposal against the exact steps provided by IEEE 802.3bz Draft 2.0 is also provided.

Introduction

This contribution provides a clarified version of the ALSNR criterion calculation based on work contributed to and adopted for the development of TIA TSB-5021. Text that goes beyond what is in TIA TSB-5021 is marked by highlight. The rearrangement and additional text provides several clarifications of the algorithm described in draft 2.0.

Also provided is a table which provides guidance to relate the steps in IEEE 802.3bz Draft 2.0 with the more explicit steps in the provided procedure. This table may be used for purposes of verifying the attached procedure matches what is provided by IEEE 802.3bz Draft 2.0.

Notes for comparison to IEEE 802.3bz Draft 2.0

The following notes may be of assistance if the reader wishes to examine the provided procedure against IEEE 802.3bz Draft 2.0.

Section in the below procedure	Notes relating to procedure provided by IEEE 802.3bz Draft 2.0
Indices	This provides additional detail not included in IEEE 802.3bz Draft 2.0 in order to make equation nomenclature clear.
Frequency points	This provides additional details not included in IEEE 802.3bz Draft 2.0 which are needed for measurement specification.
Step 1	This implement step 1 in IEEE 802.3bz Draft 2.0
Step 2	This combines steps 2, 4, 5 and 7 in IEEE 802.3bz Draft 2.0
Step 2a	This combines step 2 , 4 & 7 of IEEE 802.3bz Draft 2.0
Eq 126-24	This combines steps 2 & 7 of IEEE 802.3bz Draft 2.0
Steps 2b-2d	This is step 4 of 802.3bz D2.0, however provides additional detail on how to compute the power backoff per 802.3 standards which is not contained in IEEE 802.3bz Draft 2.0
Step 2e	This is step 5 of IEEE 802.3bz Draft 2.0
Step 3	This combines step 3 & 4 (for disturbing pairs) and step 6 in IEEE 802.3bz Draft 2.0
Step 3: Note 2	This implements the difference between steps 8 & 9 in IEEE 802.3bz Draft 2.0
Step 3a-3d	This is step 4 for disturbing pairs in 802.3bz D2.0, however provides additional detail on how to compute the power backoff per 802.3 standards which is not contained in IEEE 802.3bz Draft 2.0
Step 4	This provides additional details not included in IEEE 802.3bz Draft 2.0 which are helpful for clarity.
Step 5	This is a combination of steps 6 and (part of) 8/9 in IEEE 802.3bz Draft 2.0
Step 6	This is a combination of power sum in step 8/9 into step 10 of IEEE 802.3bz Draft 2.0, an additional noise term is added here to better model receiver losses.
Step 7	This is step 11 of IEEE 802.3bz Draft 2.0
Eq. 126-36	It should be noted the equation has been simplified to remove unnecessary complication included in IEEE 802.3bz Draft 2.0.
Step 7	IEEE 802.3bz Draft 2.0 does not specify which value of ALSNR to use but by defacto uses the lowest. Step 7 does the same.
Step 8	This is step 12 of IEEE 802.3bz Draft 2.0
Step 9	This is the iteration discussed in step 9 of IEEE 802.3bz Draft 2.0

The text below is proposed to replace 126.7.3.1:

126.7.3.1 Alien Crosstalk Limited Signal-to-Noise Ratio Criteria

Noise coupled between the disturbed duplex channel in a link segment and the disturbing duplex channels in other link segments is referred to as alien crosstalk noise. To ensure the total alien NEXT loss and alien FEXT loss coupled between link segments are limited a figure of merit denoted as the alien crosstalk limited signal-to-noise ratio criteria ($ALSNR_{criteria}$) is specified. The $ALSNR_{criteria}$ is the numerical difference between the ALSNR derived from measurements of its alien crosstalk and insertion loss parameters, denoted $ALSNR_{link}$ and the link segment SNR sufficient to support the objective BER, denoted $SNR_{linkreq}$. $SNR_{linkreq}$ includes SNR margin to account for power backoff uncertainties and the differences between what is theoretically possible and what is feasible in the implementation of receivers. An additional noise term is added to better model receiver losses which change the achievable ALSNR criterion with insertion loss.

The $ALSNR_{criteria}$ procedure enables determination of $ALSNR_{link}$ for disturbed link segments with 2.5G and 5G signalling rates from any number of disturbing link segments with all possible combinations of 1G/2.5G/5G/10G signalling rates. The selection of the number of disturbing link segments and signalling rates to consider are addressed in TIA TSB 5021 and ISO/IEC TR 11801-9904.

For a compliant 2.5GBASE-T link segment, $\mathrm{ALSNR}_{Criteria}$ shall be greater than zero for every possible permutation of 1000BASE-T and 2.5GBASE-T running on the disturbing link segments.
For a compliant 5GBASE-T link segment, $\mathrm{ALSNR}_{Criteria}$ shall be greater than zero for every possible permutation of 1000BASE-T, 2.5GBASE-T, 5GBASE-T and 10GBASE-T on the disturbing link segments.

The $ALSNR_{criteria}$ may be determined by the result of the following 9 step procedure:

Indices

i	1-4	pair of the disturbed link segment
k	1-4	pair of the disturbing link segment
m	1- M	index of the disturbing link segment
M		is the number of disturbing link segments.

Step 1.
Measure the insertion loss of all the pairs in the disturbed link segment and the disturbing link segments in the frequency range given by Table 126-20.

Table 126-20 - Frequency range of IL measurements

Application Running on the Disturbed Link Segment	Frequency range of Measurement
2.5GBASE-T	1 ≤ f ≤ 100 MHz
5GBASE-T	1 ≤ f ≤ 200 MHz

Denote each pair of the disturbed link segment insertion loss as $IL_{disturbed_i}$
Denote each pair of the disturbing link segment insertion loss as $IL_{disturbing_{k,m}}$

where i denotes the pair of the disturbed link segment, k denotes the pair of the disturbing link segment and m denotes the index number of the disturbing link segment.

NOTE—While disturbing signals may contain higher frequencies, the received power, which determines the power back off, is dominated by the power below 100 MHz. Neglecting the higher frequencies has no appreciable effect in computing the 10GBASE-T or 5GBASE-T power back off.

Step 2
Determine the Received Signal Transmit Power including PBO, S_i, for each pair, i, of the disturbed link segment, at each frequency point.

Step 2a.

Determine the nominal (i.e., without power backoff) Received Signal Transmit Power for each pair of the disturbed link segment, $Rx\_TP\_dBm_{disturbed_i}$, at each frequency point by using Equation (126-24).

$$Rx_{TP_{dBm\,disturbed_i}}(f) = TemplatePSD_{disturbed}(f) - IL_{disturbed_i}(f) \qquad (dBm/Hz)$$ **(126-24)**

where $TemplatePSD_{disturbed}$ is provided by Table 126-21, according to which application is running on the disturbed link segment, this must be the same selection as the frequency range selected in Step 1.

Table 126-21 – Template PSD for disturbed link segment

Application Running on the Disturbed Link segment	Template PSD (dBm/Hz)
2.5GBASE-T	$-77.9 + 20log_{10}\left(\frac{\left\|sin\left(\frac{\pi f}{200}\right)\right\|}{\left(\frac{\pi f}{200}\right)}\right) - 10log_{10}\left(1+\left(\frac{f}{490}\right)^4\right)$
5GBASE-T	$-80.7 + 20log_{10}\left(\frac{\left\|sin\left(\frac{\pi f}{400}\right)\right\|}{\left(\frac{\pi f}{400}\right)}\right) - 10log_{10}\left(1+\left(\frac{f}{490}\right)^4\right)$

Step 2b.

Calculate the Received Signal Transmit power, for each pair of the disturbed link segment, i, at each frequency point, to a linear magnitude and multiply by the frequency step size in Hz.

$$Rx\_TP_{mW\,disturbed_i}(f) = \Delta f\left(10^{\left(\frac{Rx\_TP\_dBm_{disturbed_i}(f)}{10}\right)}\right) \qquad (mW)$$ **(126-25)**

where Δf is the step size between frequency points at that data point in Hz.

Step 2c.

Calculate the Total Received Power in dBm, $Total\_Rx\_TP_{dBm\,disturbed_i}$, for each pair, i, of the disturbed cable.

$$Total\_Rx\_TP_{dBm\,disturbed_i} = 10log_{10}\left(\sum_{f=f_{min}}^{f_{max}} Rx\_TP_{mW\,disturbed_i}(f)\right)$$ **(126-26)**

where f_{min} and f_{max} are provided by Table 126-20.

Step 2d.

Determine the Power Back Off for the disturbed cable, $PBO_{disturbed}$, by calculating the mean value of $Total\_Rx\_TP_{dBm\,disturbed_i}$ across the pairs using Equation 126-27, and determining $PBO_{disturbed}$ from Table 126-12 for 2.5GBASET, or for 5GBASET, depending on which PHY the disturbed link segment is being qualified for.

For each value of m:-

$$\overline{Rx\_TP_{disturbed}} = \frac{\left(\sum_{i=1}^{i=4} Total\_Rx\_TP_{dBm\,disturbed_i}\right)}{4}$$ **(126-27)**

Step 2e.

Calculate the Received Signal Transmit PSD including PBO, S_i, for each pair of the disturbed link segment at each frequency point by using Equation 126-28.

For i = 1 to 4:-

$$S_i(f) = Rx\_TP\_dBm_{disturbed_i}(f) - PBO_{disturbed} \qquad \textbf{(126-28)}$$

Step 3

For each disturber type being evaluated on a disturbing link segment (see Step 9 for more detail), determine the Power Back Off for the disturber type running on each disturbing link segment, PBO_m. This step involves selecting which application is running on each disturbing link segment (see Step 8 for further details of calculations for all possible permutations).

Note 1: The PBO for 1000BASE-T is always 0dB, and the calculations of this step do not apply.
Note 2: When 2.5GBASE-T is running on the disturbed link segment, then the calculations only need to consider 2.5GBASE-T and 1000BASE-T running on the disturbing link segments.

Step 3a.

Determine the nominal (i.e., without power backoff applied) Received Signal Transmit Power, $Rx\_TP\_dBm_{disturbing_{k,m}}(f)$, for each pair, k, of the disturbing link segment, m, at each frequency point by using Equation (126-29):

$$Rx\_TP\_dBm_{disturbing_{k,m}}(f) = TemplatePSD_m(f) - IL_{disturbing_{k,m}}(f) \quad \text{(dBm/Hz)} \qquad \textbf{(126-29)}$$

where $TemplatePSD_m$ is provided by Table , for the disturber type being evaluated.

Table 126-22 – Template PSD for disturbing link segment

Application Running on the Disturbing Link segment	Template PSD (dBm/Hz)
1000BASE-T	$-72.4 + 20log_{10}\left(\frac{\left\lvert sin\left(\frac{\pi f}{125}\right)\right\rvert}{\left(\frac{\pi f}{125}\right)}\right) - 10log_{10}\left(1+\left(\frac{f}{100}\right)^2\right) + 10log_{10}\left(0.625 + 0.375cos\left(\frac{2\pi f}{125}\right)\right)$
2.5GBASE-T	$-77.9 + 20log_{10}\left(\frac{\left\lvert sin\left(\frac{\pi f}{200}\right)\right\rvert}{\left(\frac{\pi f}{200}\right)}\right) - 10log_{10}\left(1+\left(\frac{f}{490}\right)^4\right)$
5GBASE-T	$-80.7 + 20log_{10}\left(\frac{\left\lvert sin\left(\frac{\pi f}{400}\right)\right\rvert}{\left(\frac{\pi f}{400}\right)}\right) - 10log_{10}\left(1+\left(\frac{f}{490}\right)^4\right)$
10GBASE-T	$-80.89 + 20log_{10}\left(\frac{\left\lvert sin\left(\frac{\pi f}{800}\right)\right\rvert}{\left(\frac{\pi f}{800}\right)}\right) - 10log_{10}\left(1+\left(\frac{f}{490}\right)^4\right)$

Step 3b.

Convert the Received Signal Transmit power for each pair, k, of each disturbing link segment, m, at each frequency point to a linear magnitude and multiply by the frequency step size:

$$Rx\_TP\_mW_{disturbing_{k,m}}(f) = \Delta f\left(10^{\left(\frac{Rx\_TP\_dBm_{disturbing_{k,m}}(f)}{10}\right)}\right) \quad \text{(mW)} \qquad \textbf{(126-30)}$$

where Δf is the step size between frequency points at that data point in Hz (not MHz).

Step 3c.
Calculate the Total Received Power in dBm, for each pair, k, of each disturbing link segment, m, by adding the values at each frequency point and converting to dBm using Equation (126-31).

$$Total\_Rx\_TP\_dBm_{disturbing_{k,m}} = 10log_{10}\left(\sum_{f=f_{min}}^{f_{max}} Rx\_TP\_mW_{disturbing_{k,m}}(f)\right) \quad \text{(dBm)} \qquad \textbf{(126-31)}$$

where f_{min} and f_{max} are provided by Table 126-20.

Step 3d.
Determine the Power Back Off, PBO_m, for each disturbing link segment, m, by calculating the mean value of $Total\_Rx\_TP\_dBm_{disturbing_{k,m}}$ across the pairs, using Equation (126-32) for each link segment, and then determining PBO_m from Table 126-12 for 2.5GBASET and 5GBASE-T, and Table 55-11 for 10GBASET running on the disturbing link segment.
The PBO for 1000BASE-T is always 0dB.

For each value of m:

$$\overline{Rx\_TP_{disturbing_m}} = \frac{\sum_{k=1}^{k=4} Total\_Rx\_TP\_dBm_{disturbing_{k,m}}}{4} \qquad \textbf{(126-32)}$$

Step 4
Measure the ANEXT and AFEXT combinations for each disturbing link segment, m.
Each disturbing link segment will provide 16 ANEXT combinations and 16 AFEXT combinations.

Denote the measurements as $ANEXT_{measurement_{i,k,m}}$, and $AFEXT_{measurement_{i,k,m}}$.

Where:-

i	1-4	is the pair of the disturbed link segment
k	1-4	is the pair of the disturbing link segment
m	1- M	is the index of the disturbing link segment
M		is the number of disturbing link segments.

Step 5
Calculate the alien crosstalk components including PBO for each Alien crosstalk measurement for each disturbing link segment at each frequency point using Equation (126-33) and Equation (126-34). Note that the frequency points must be measured or interpolated to the same frequencies used for the insertion loss measurements:

$$ANEXT_{component_{i,k,m}}(f) = TemplatePSD_m(f) - ANEXT_{measurement_{i,k,m}}(f) - PBO_m \qquad \textbf{(126-33)}$$

$$AFEXT_{component_{i,k,m}}(f) = TemplatePSD_m(f) - AFEXT_{measurement_{i,k,m}}(f) - PBO_m \qquad \textbf{(126-34)}$$

where *TemplatePSD$_m$(f)* and *PBO$_m$(f)* are from Steps 3a and 3d, respectively.

Step 6
Calculate the total noise received by each pair, i, of the disturbed link segment by powersumming the ANEXT and AFEXT Components together at each frequency point:

For i = 1 to 4:-

$$N_i(f) = 10log_{10}\left(\sum_{m=1}^{M}\sum_{k=1}^{4}\left(\left(10^{\left(\frac{ANEXT_{component_{i,k,m}}(f)}{10}\right)}\right) + \left(10^{\left(\frac{AFEXT_{component_{i,k,m}}(f)}{10}\right)}\right)\right) + \left(10^{\left(\frac{add\_noise}{10}\right)}\right)\right) \qquad \textbf{(126-35)}$$

where M is the number of disturbing link segments, and *add_noise* is in Table 126-23.

Table 126-23 – Values of add_noise noise term

Application Running on the Disturbed Link Segment	**Value of impl_comp**
2.5GBASE-T	-TBD1 dBm/Hz
5GBASE-T	-TBD2 dBm/Hz

Step 7

Calculate the Alien Signal to Noise Ratio, ALSNR for each pair, i, of the disturbed link segment by using Equation (126-36):

$$\mathrm{ALSNR}_i = \left(\frac{1}{f_{max}}\right) \sum_{f=f_{min}}^{f_{max}} (S_i(f) - N_i(f))\Delta f$$ **(126-36)**

where f_{max} and Δf are the maximum frequency, and the step size between frequency points at that data point in the same frequency units (e.g., both MHz or both Hz).

Determine the minimum of ALSNR_i, across all pairs, providing ALSNR_{link}.

Step 8

Calculate $\mathrm{ALSNR}_{Criteria}$ using Equation (126-37):

$$\mathrm{ALSNR}_{Criteria} = \mathrm{ALSNR}_{link} - \mathrm{SNR}_{linkreq}$$ **(126-37)**

where $\mathrm{SNR}_{linkreq}$= 28 dB.

Step 9- Multiplicity

Steps 1-8 determine the ALSNR_{link} for a given application running on the disturbed link segment, and a given permutation of applications running on the disturbing link segments.

To calculate the worst case permutation of disturbers running on the disturbing link segment, repeat steps 3-8 using every possible permutation of disturbers running on the disturbing link segments, and determine $\mathrm{ALSNR}_{criteria}$ for each permutation of disturbing applications.