Alien Crosstalk Margin Computation

September 2005
Nashua, NH

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Alien Crosstalk Margin Calculation

- An alien crosstalk margin calculation is offered to further characterize the alien crosstalk coupling “between” link segments.

- The alien crosstalk margin computation ensures the total combined PSAFEXT and PSANEXT coupled into a duplex channel is limited in order to maintain the minimum signal to noise ratio.

- The alien crosstalk margin is specified for each of the individual 4-pairs as well as the average “across the 4-pairs”.

- The margin is calculated based on “averaging across frequency” the difference between the measured alien crosstalk and the alien crosstalk limits expressed in dB.

- The margin must be greater than 0 to utilize the cabling for 10GBASE-T operation.

Alien crosstalk Margin Calculation: Rationale

- **Limit line pass/fail criteria to pessimistic**
  - "Peak" to limit failures not good indicator of operational performance
  - Out-of band "peak" failures eliminated
  - Pass/fail criteria defined in one parameter
  - Eliminates separate ANEXT and AFEXT pass/fail limits
- **Allows for ANEXT vs. AFEXT tradeoffs**
  - A limit line "failure" for one alien crosstalk type may be compensated by margin in the other.
  - Increases the percentage of installed base of category 6 cabling that would qualify to support 10GBASE-T
- **Correlates with receiver signal-to-noise ratio (SNR) margin**
  - SNR margin is an accurate estimator of operational performance
- **Accounts for benefit of LDPC channel coding across all four pairs**
  - Coding averages alien crosstalk impairment across all four pairs

Practical Issues with SNR Calculations

- **Direct SNR calculation can include many implementation dependent parameters choices**
  - receiver implementation loss
  - internal cabling impairments (residual echo, NEXT, FEXT, and background noise) included in *N(f)*
  - transmit PSD template *S(f)*
- **SNR calculation algorithm**
  - Frequency point spacing for measurement and integration
  - Selection of number of SNR folds in calculation
- **Alien crosstalk margin eliminates the PHY dependencies in an exact SNR margin calculation**

Individual-Pair Margin Calculation:

Step 1. XW(f) is calculated for each of the 4-pairs

Let XW(f) = - 10*log10(10^(-0.1*AN(f)) + 10^(-0.1*AF(f)))
+ 10*log10(10^(-0.1*(AN_IPL(f)+2.5)) + 10^(-0.1*(AF_IPL(f))))

Where:

AN(f) = measured PSANEXT Loss in dB from f=10 MHz to f=400 MHz
AF(f) = measured PSAFEXT Loss in dB from f=10 MHz to f=400 MHz

AN_IPL(f)= Individual-pair limit line for PSANEXT as specified in 802.3an D2.1 equation 55-23 utilizing the measured insertion loss of the individual-pair.

***Note: The 2.5 dB is the PSANEXT allowance for the peak-to-average difference across frequency

AF_IPL(f) = Individual-pair limit line for PSAFEXT calculated from the PSAELFEXT equation specified in 55.28 utilizing the measured insertion loss of the individual-pair.

Individual-Pair Margin Calculation:

Step 2. Calculate average value "across frequency" of XW(f)

Take the average value "across frequency" of XW(f) from 10 to 400 MHz, for each individual-pair of the 4-pair cabling, let these be XW1, XW2, XW3, XW4.

Let Yinp = min (XW1, XW2, XW3, XW4).

If Yinp < 0 then the cabling fails the "individual-pair" test and you can stop here.

Average Margin Calculation:

Step 3. Calculate XA(f)

Let XA(f) = - 10*log10(10^(-0.1*AN_AVG(f)) + 10^(-0.1*AF_AVG(f)))
+ 10*log10(10^(-0.1*(AN_AVGL(f)+2.5)) + 10^(-0.1*(AF_AVGL(f))))

Where:

AN_avg(f) = Average measured PSANEXT Loss in dB "across the 4 pairs".

AF_avg(f) = Average measured PSAFEXT Loss in dB "across the 4 pairs".

AN_AVGL(f)= Average limit line for PSANEXT as specified in 802.3an D2.1 equation 55-24 where the coefficient for the equation is the minimum of the individual-pair PSANEXT coefficients.

AN_AVGL(f)=(min(PSANEXT_coefficients)+1)-10*LOG(fMHz)/100) 1≤fMHz≤100
=(min(PSANEXT_coefficients)+1)-15*LOG(fMHz)/100) 100<fMHz≤500

***Note: The 2.5 dB is the PSANEXT allowance for the peak-to-average difference across frequency

Average Margin Calculation:

AF_AVGL(f)= Average limit line for PSAFEXT obtained by adding the measured IL from the pair with the minimum AELFEXT coefficient to the PSAELFEXT limit specified in 802.3an D2.1 equation 55-29 where the coefficient for the equation is the minimum of the individual-pair PSAELFEXT coefficients.

AF_AVGL(f) = (min(PSAELFEXT_coefficients)+4) -20*LOG(fMHz)/100)+ (measured IL of pair with minimum PSAELFEXT coefficient)

<u>Step 4. Calculate average value "across frequency" of XA(f)</u>

Let Yavg = the average value "across frequency" of XA(f) from 10 to 400 MHz

The margin of the cabling to the "average" test is Yavg dB. The cabling fails this test if Yavg < 0.

Alien crosstalk margin calculation

The link segment margin calculation is defined by the equation:

YL = min (Yinp, Yavg)
YL > 0 is required for a pass

<u>Where:</u>

Yinp is the average value "across frequency" of XW(f) from 10 to 400 MHz.

Yavg the average value "across frequency" of XA(f) from 10 to 400 MHz.

Both Yinp and Yavg must be > 0 for the cabling to pass.

The link segment margin is YL = min(Yinp,Yavg)

Reference SNR Calculation

- **SNR calculated utilizing channel models (reference SNR)**
  - **PSAELFEXT and PSANEXT individual-pair and average constants calculated for each channel model**
  - **Only the Alien crosstalk impairments included in calculation**
  - **Apply Saltz SNR formula with single Nyquist fold (0 – 400 MHz);**
    - **Channel #1 (100m Class F): SNR_{PAIR1} = 27.72 dB SNR_{AVG1} = 29.78 dB**
    - **Channel #2 (100m Class E): SNR_{PAIR2} = 27.95 dB SNR_{AVG2} = 29.99 dB**
    - **Channel #3 (55m Class E): SNR_{PAIR3} = 26.34 dB SNR_{AVG3} = 28.49 dB**

Margin Calculations

1. The measurement data SNR is calculated and a margin with respect to the minimum reference SNR.

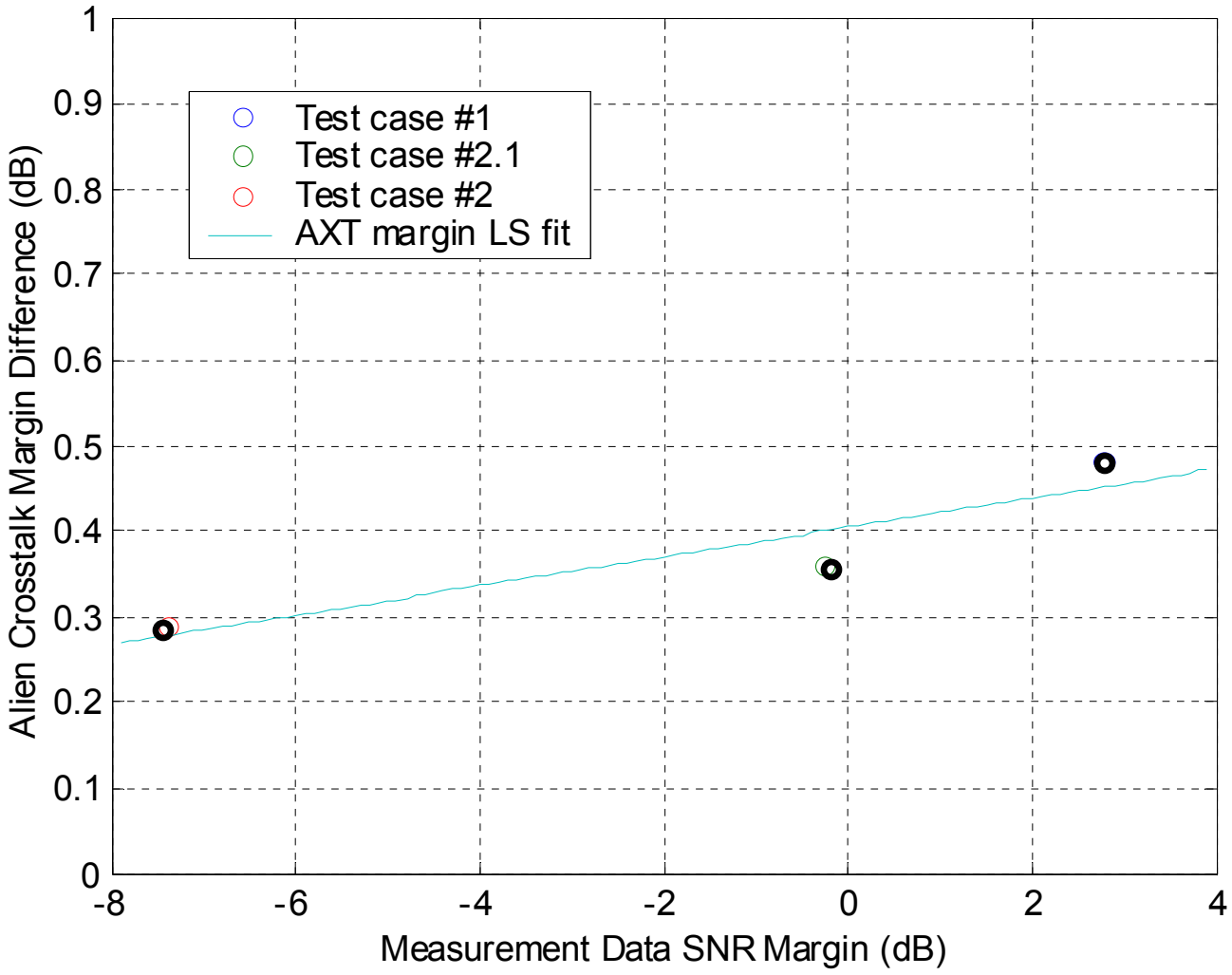
2. The Alien crosstalk computation is applied to the measurement data and a margin is calculated.

3. A PSANEXT and PS AELFEXT strict limit line margin is calculated
   - minimum margin from the limit line for each of the 4-pairs
   - PSANEXT and PSAELFEXT limit lines examined separately

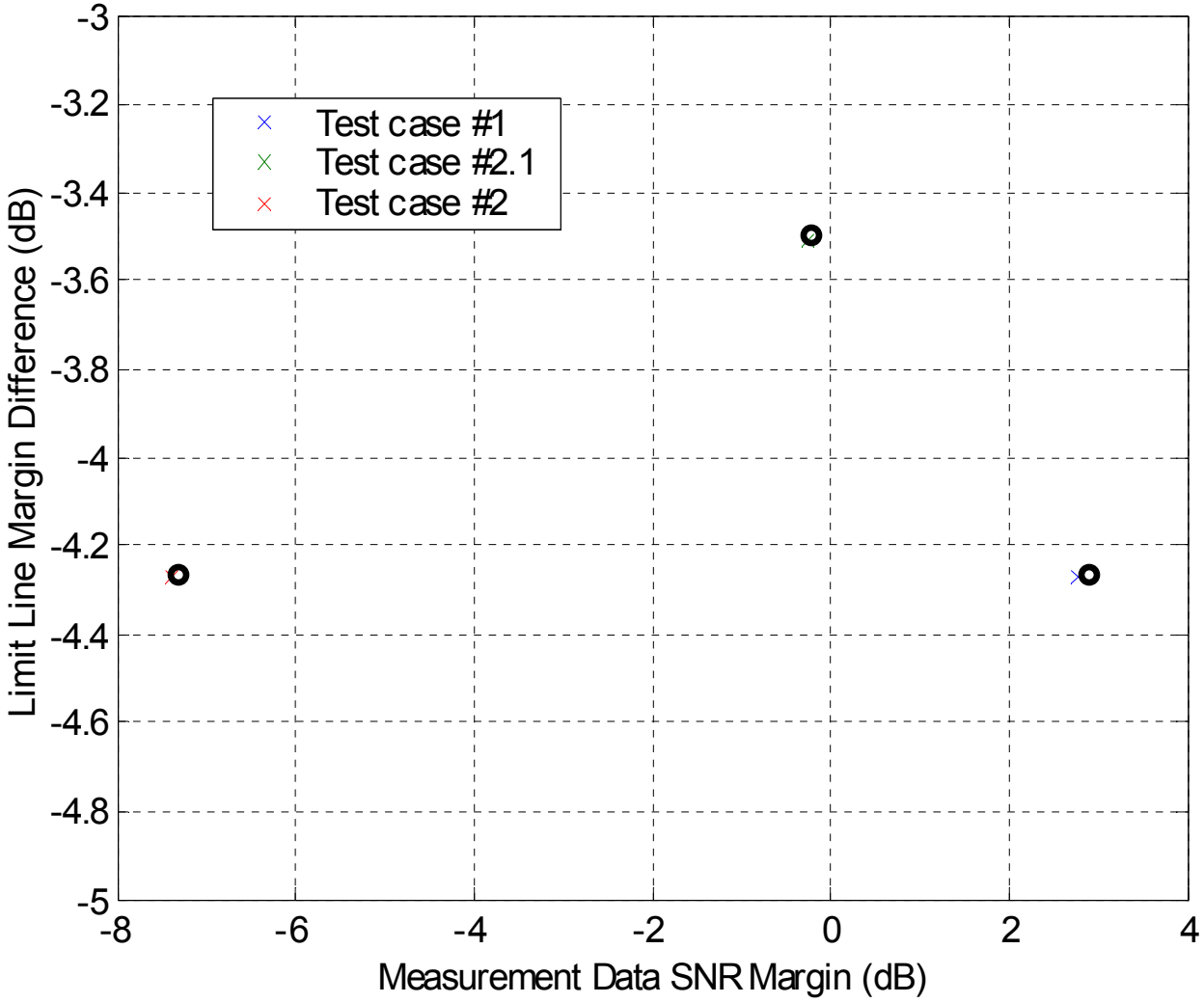
Margin comparisons (dB)

Test case	Measurement data SNR margin	Alien Crosstalk Computation margin	PSANEXT strict limit line margin	PSAELFEXT strict limit line margin
Test case#1 55 meter Cat 6 bundled w/ mitigation	Pair 1 = 14.62 Pair 2 = 2.76 Pair 3 = 11.50 Pair 4 = 6.23 Average = 6.63 Min(P,Avg) = 2.76	Pair 1 = 14.98 Pair 2 = 3.24 Pair 3 = 11.92 Pair 4 = 6.71 Average = 7.19 Min(P,Avg) = 3.24	Pair 1 = 16.04 Pair 2 = 9.47 Pair 3 = 15.63 Pair 4 = 7.74 Average = 12.25 Min(P,Avg) = 7.74	Pair 1 = 11.10 Pair 2 = -1.51 Pair 3 = 8.26 Pair 4 = 2.71 Average = 2.01 Min(P,Avg) = -1.51
Test Case#2 55 meter Category 6 bundled	Pair 1 = -4.55 Pair 2 = -5.00 Pair 3 = -5.46 Pair 4 = -5.89 Average = -7.38 Min(P,Avg) = -7.38	Pair 1 = -4.35 Pair 2 = -4.82 Pair 3 = -5.24 Pair 4 = -5.74 Average = -7.09 Min(P,Avg) =-7.09	Pair 1 = -1.17 Pair 2 = -3.98 Pair 3 = -2.07 Pair 4 = -2.13 Average = -1.67 Min(P,Avg)=-3.98	Pair 1 = -7.54 Pair 2 = -6.94 Pair 3 = -8.34 Pair 4 = -9.21 Average = -11.65 Min(P,Avg)= -11.65
Test Case#2.1 55 meter Category 6 unbundled	Pair 1 = 2.77 Pair 2 = 2.59 Pair 3 = 0.33 Pair 4 = 1.83 Average = -0.27 Min(P,Avg) = -0.27	Pair 1 = 3.04 Pair 2 = 2.84 Pair 3 = 0.61 Pair 4 = 2.10 Average = 0.09 Min(P,Avg) = 0.09	Pair 1 = 4.15 Pair 2 = -2.64 Pair 3 = 2.35 Pair 4 = 1.47 Average = 3.18 Min(P,Avg) = -2.64	Pair 1 = 0.48 Pair 2 = 0.93 Pair 3 = -2.62 Pair 4 = -0.44 Average = -3.78 Min(P,Avg) = -3.78

Alien Crosstalk Margin vs. Measurement SNR Margin



Strict Limit Line Margin vs. Measurement SNR Margin



Margin relative to SNR reference

Observations from Example Calculations

- **Difference between reference SNR margin and alien crosstalk computation margin < 0.4 dB at 0 dB threshold**
  - **Correlation is no accident since the reference SNR margin is computed from the ANEXT and AFEXT**
  - **Predictable correlation near 0 dB margin threshold (very important)**
  - **Measured data fits to line; predictable correlation pattern**

- **Strict PS ANEXT and PS AELFEXT limit line pass/fail criteria yields pessimistic results (> 4 dB worse) compared to reference SNR margin**
  - **Channels that have acceptable operating margin would fail a strict limit line qualification test**
  - **No apparent correlation pattern; random scatter**

Conclusion(s)

- **Separate limit line pass/fail criteria yields pessimistic results compared to true SNR margin**
  - Channels that are acceptable in terms of SNR margin would fail a strict limit line qualification test
  - Does not allow for tradeoffs between ANEXT and AFEXT
  - Does not account for channel coding across all four pairs
- **Proposed alien crosstalk margin calculation method is a potential alternative to exact SNR calculation**
  - More accurate indicator of system performance than strict limit line pass/fail criteria
  - Eliminates subjectivity of exact SNR calculations and direct limit line test