Noise considerations for 40/100GBASE-CR4/10

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Insertion loss to crosstalk ratio – Comments #141, #293

- Insertion loss to crosstalk ratio (ICR) limit predicts a larger RMS crosstalk amplitude than what may be derived from the measured cable assembly crosstalk transfer functions

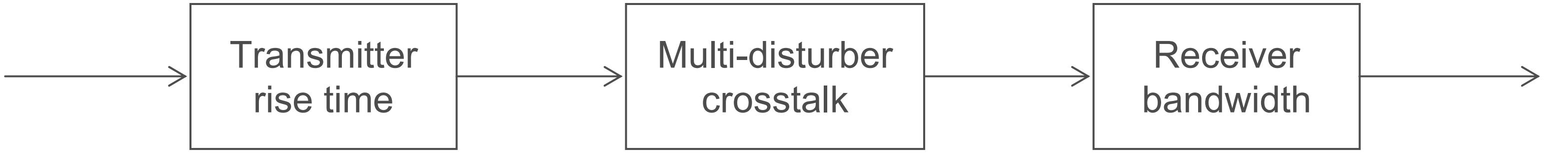
- The ICR is used as the basis for definition of the random interference stress applied during receiver testing (note 1)
  - Why not apply the same calculation to the cable assembly and achieve a clearer coupling between cable assembly and receiver requirements?

- It has been pointed out (note 2) that the log-linear fit to the calculated ICR sometimes produces limit violations even the calculated data appears to be in the acceptance region
  - It turns out that, for the specific case cited, this behavior was due to an error in the calculation of ICR
  - With the error corrected, the calculated ICR violated the limit hence the log-linear fit was not producing a false negative in this case

NOTE 1 – Refer to http://ieee802.org/3/ba/public/nov08/healey_01_1108.pdf.
NOTE 2 – Refer to http://ieee802.org/3/ba/public/may09/balasubramanian_01_0509.pdf.

Integrated crosstalk noise model

$$\left|H_{nx}(f)\right|^2 = 10^{-MDNEXT_{loss}(f)/10} \qquad \left|H_{fx}(f)\right|^2 = 10^{-MDFEXT_{loss}(f)/10}$$



$$\left|H_t(f)\right|^2 = \frac{1}{1+\left(f\,T_r/0.2365\right)^4} \qquad \left|H_r(f)\right|^2 = \frac{1}{1+\left(f/f_r\right)^8}$$

- $MDNEXT_{loss}$ and $MDFEXT_{loss}$ are defined in 85.10.5 and 85.10.6 respectively
- Define the transmitter output pulse shape in terms of a second order Butterworth filter where the 20% to 80% rise time T_r
- Assume a fourth order Butterworth receiver filter with –3 dB bandwidth f_r equal to 7.5 GHz

Integrated crosstalk noise definition – 1

Given the cable assembly TP1 to TP4 multi-disturber near-end crosstalk loss $MDNEXT_{loss}$ and multi-disturber far-end crosstalk loss $MDFEXT_{loss}$ measured over N frequencies f_n spanning 50 MHz to 10 GHz with a uniform frequency step Δf, the RMS value of the integrated crosstalk noise shall be calculated as follows.

Define the weight at each frequency f_n using Equation (1) and Equation (2).

$$W_{nt}(f) = A_{nt}^2 (\Delta f / f_b) \operatorname{sinc}^2 (f / f_b) \left[\frac{1}{1 + (f T_{nr} / 0.2365)^4} \right] \left[\frac{1}{1 + (f / f_r)^8} \right] \quad (1)$$

$$W_{ft}(f) = A_{ft}^2 (\Delta f / f_b) \operatorname{sinc}^2 (f / f_b) \left[\frac{1}{1 + (f T_{fr} / 0.2365)^4} \right] \left[\frac{1}{1 + (f / f_r)^8} \right] \quad (2)$$

Integrated crosstalk noise definition – 2

The near-end crosstalk integrated noise σ_{nx} is calculated using Equation (3).

$$\sigma_{nx} = \left(2 \sum_{n} W_{nt}(f_n) 10^{-MDNEXT_{loss}(f_n)/10} \right)^{1/2} \tag{3}$$

The far-end crosstalk integrated noise σ_{fx} is calculated using Equation (4).

$$\sigma_{fx} = \left(2 \sum_{n} W_{ft}(f_n) 10^{-MDFEXT_{loss}(f_n)/10} \right)^{1/2} \tag{4}$$

The total integrated noise σ_x is calculated using Equation (5).

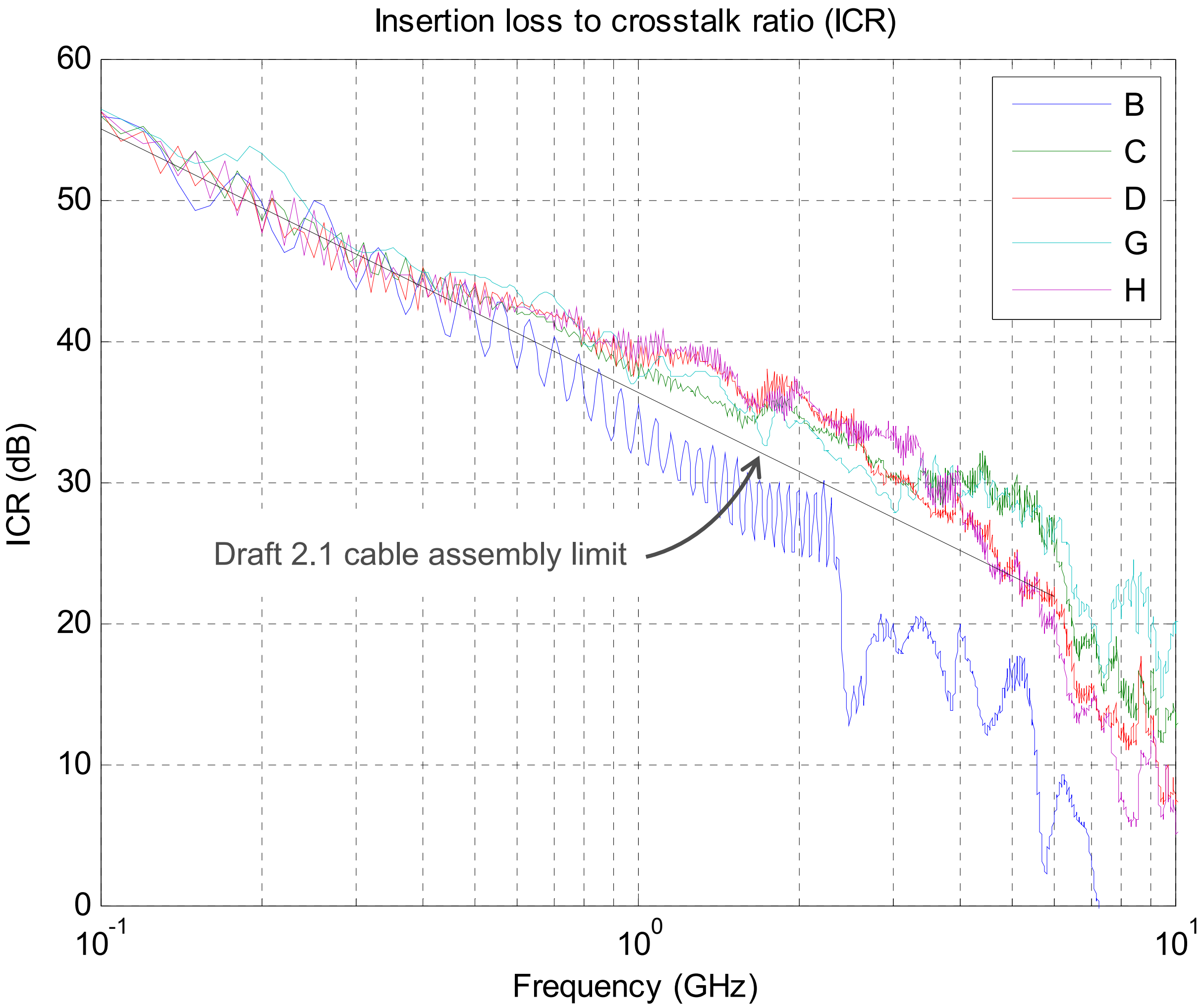
$$\sigma_x = \sqrt{\sigma_{nx}^2 + \sigma_{fx}^2} \tag{5}$$

Integrated crosstalk noise parameters

Parameter	Symbol	Value	Units
Signaling rate	f_b	10.3125	GBd
Near-end aggressor peak differential output voltage	A_{nt}	600	mV
Far-end aggressor peak differential output amplitude	A_{ft}	480	mV
Near-end aggressor 20 to 80% rise and fall times	T_{nr}	24	ps
Far-end aggressor 20 to 80% rise and fall times	T_{fr}	41	ps
Receiver −3 dB bandwidth	f_r	7.5	GHz

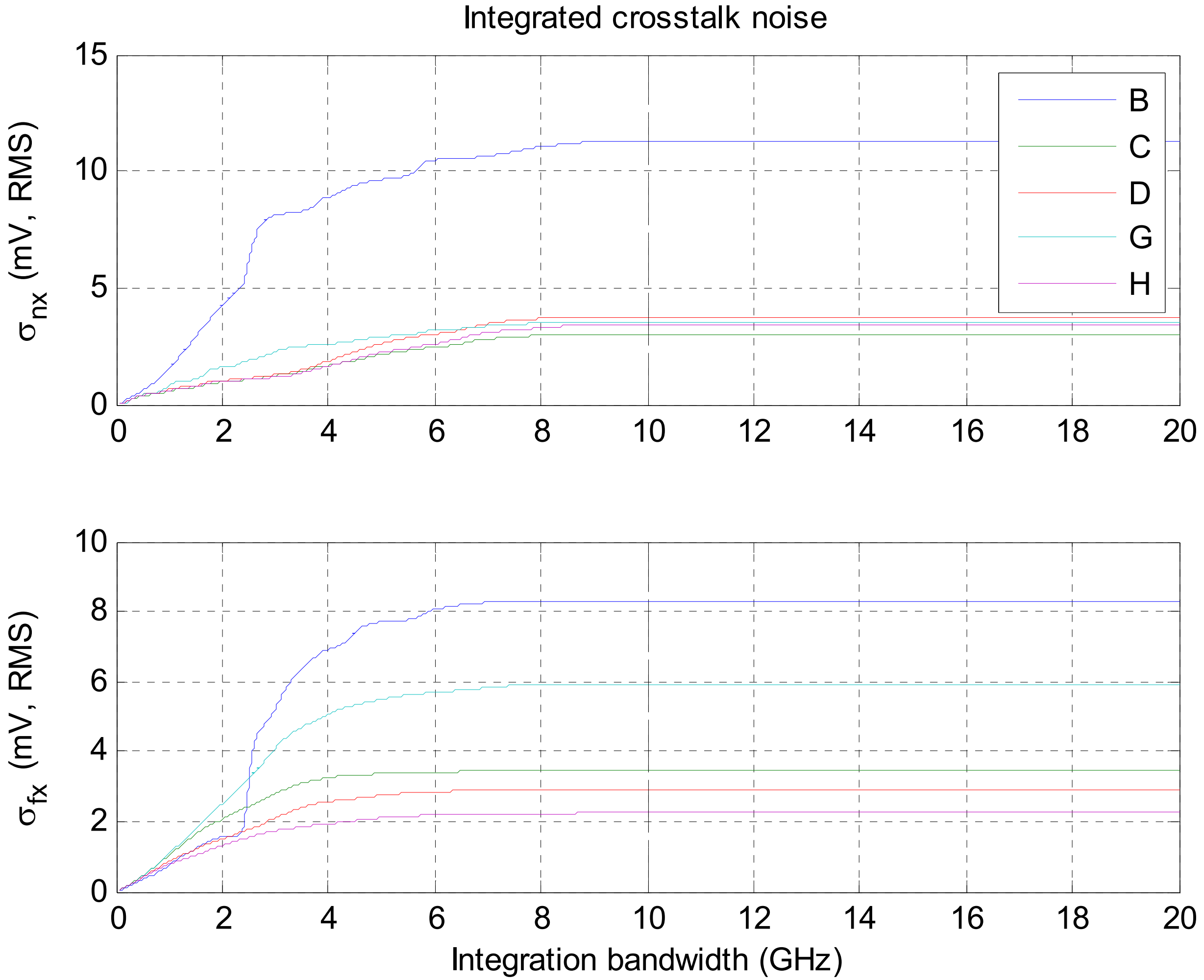
NOTE – Assumes ± 8.5% parametric matching between transmitters associated with the interface. The victim transmitter is assumed to have worst-case parameters (800 mV differential peak-to-peak output voltage, 47 ps 20 to 80% rise time)

Insertion loss to crosstalk ratio



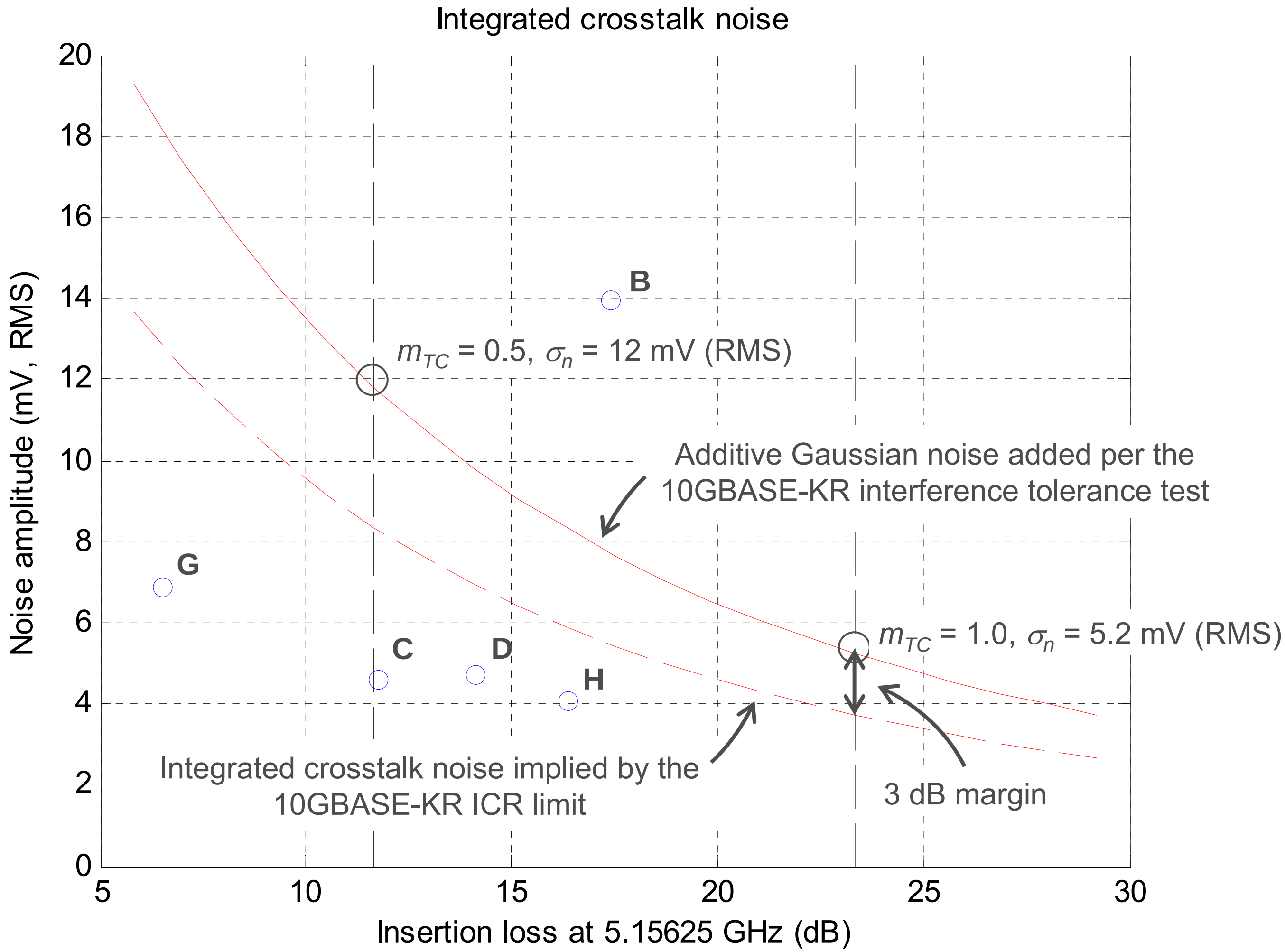
NOTE 1 – Sample B corresponds to a 3 m cable assembly with Style 2 MDI (refer to http://ieee802.org/3/ba/public/channel.html)

Integrated crosstalk noise (ICN)



An integration bandwidth of 10 GHz is sufficient to capture all of the noise

ICN versus insertion loss



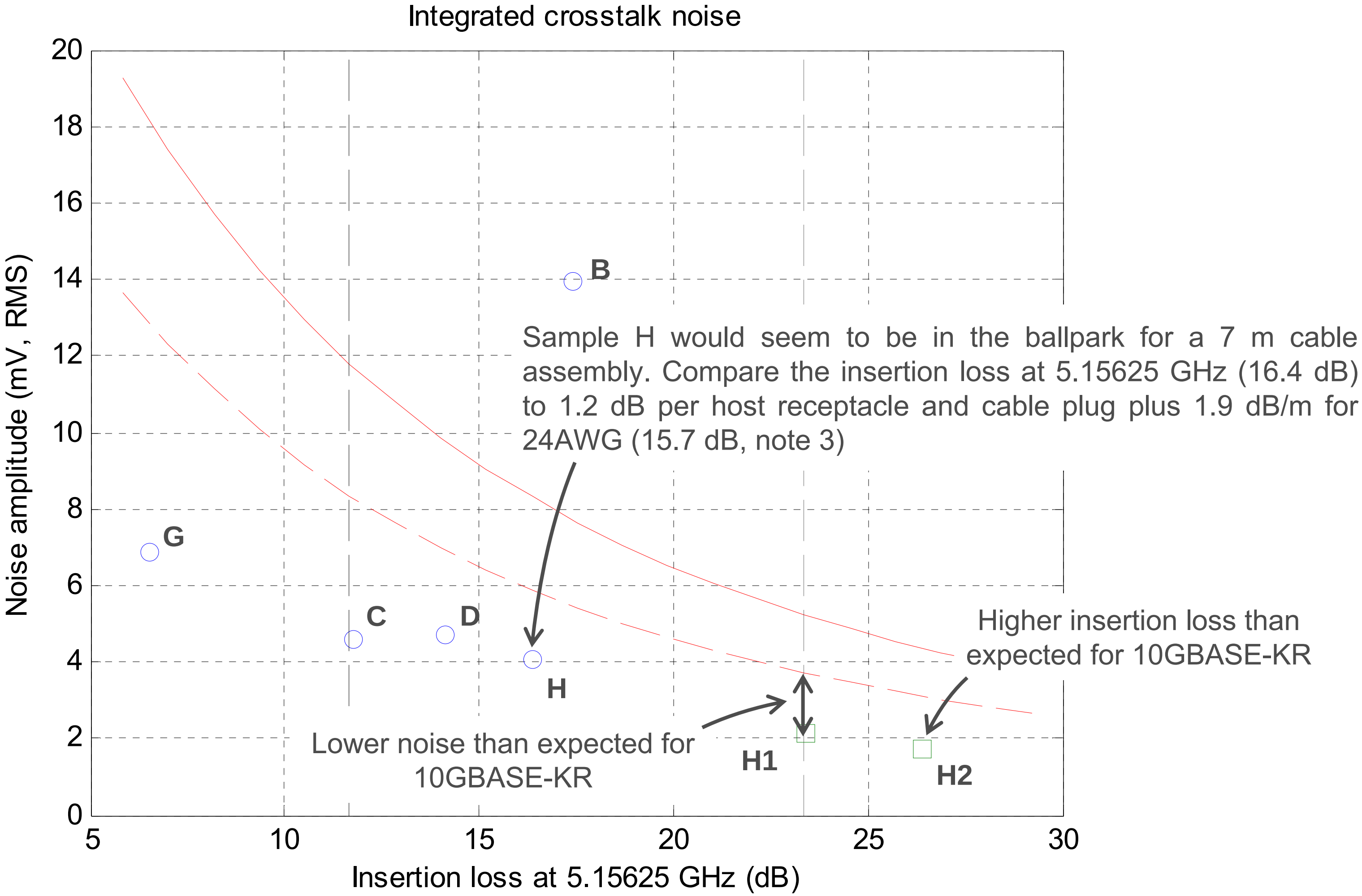
Host printed circuit board allowance – Comment #96

- Comment #96 suggests that the host printed circuit board (PCB) and connector insertion loss allowance be increased
  - 5.0 dB at 5.15625 GHz for the PCB trace, connector, and other impairments
  - 3.5 dB at 5.15625 GHz for the PCB trace only

- To maintain a consistent loss budget, it is recommended that the cable assembly reach objective be reduced to 7 m
  - It is unclear how to minimize double-counting of losses since the mated connectors are included in both the host and cable assembly allowances but there may be differences in the receptacle on the cable assembly test fixture and the receptacle on the host board

- Reconsider the noise calculations with additional host-related losses
  - Assume that the crosstalk coupling between the differential PCB traces is small enough to be ignored

ICN with host printed circuit boards



Sample H would seem to be in the ballpark for a 7 m cable assembly. Compare the insertion loss at 5.15625 GHz (16.4 dB) to 1.2 dB per host receptacle and cable plug plus 1.9 dB/m for 24AWG (15.7 dB, note 3)

Higher insertion loss than expected for 10GBASE-KR

Lower noise than expected for 10GBASE-KR

NOTE 1 – Sample H1 is sample H plus host transmitter and host receiver PCB traces (each exhibiting 3.5 dB insertion loss at 5.15625 GHz).
NOTE 2 – Sample H2 is sample H plus host transmitter and host receiver PCB traces (each exhibiting 5.0 dB insertion loss at 5.15625 GHz).
NOTE 3 – Source: Chris DiMinico

Observations

- 10GBASE-KR compliant solutions support a 7 m cable assembly with host transmitter and receiver printed circuit board traces each exhibiting an insertion loss of 3.5 dB at 5.15625 GHz with margin

- The insertion loss for a channel that includes 5.0 dB of printed circuit board trace loss at both the transmitter and receiver exceeds what is currently required for 10GBASE-KR receiver testing
  - Existing solutions may support this operating point but no general statements may be made based on the 10GBASE-KR specifications alone

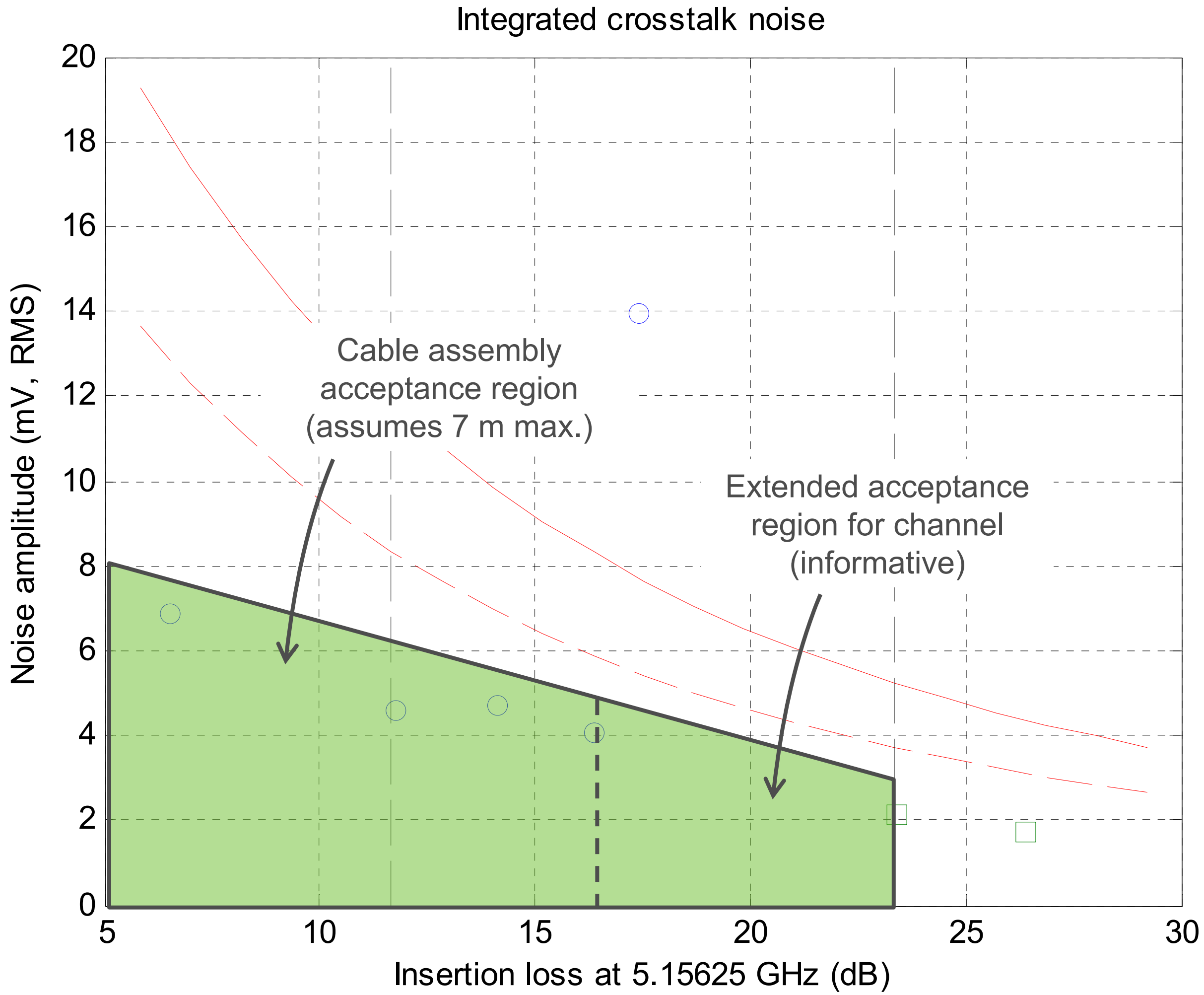
- It is again important to note that the 5.0 dB case double-counts losses that included in both the host and cable assembly allowances

Comments #141, #293 – Proposal

- Replace existing insertion loss to crosstalk ratio specifications for the cable assembly and channel with integrated crosstalk noise specifications

- Define a region of compliance for the integrated crosstalk noise based on the insertion loss at the fundamental frequency exhibited by the victim pair

Region of compliance – Example



Cable assembly acceptance region (assumes 7 m max.)

Extended acceptance region for channel (informative)

Transmitter noise testing – Comments #127, #137

- Table 85-4 specifies near-end and far-end noise characteristics and references 85.8.3.1 for the definition of how these characteristics should be measured
  - The origin of these (maximum?) limits is unclear
  - A sophisticated measurement procedure is described but it is ambiguous in multiple areas making the standard difficult to use and possibly leading to inconsistent results

- A noise characterization methodology based on the integrated crosstalk noise may lead to a simplification in transmitter output noise verification

Comments #127, #137 – Proposal (1 of 3)

- Define two reference cable assemblies
  - A low loss cable assembly whose insertion loss on the observed pair at the fundamental frequency is 6.0 dB ± 1.5 dB
  - A high loss cable assembly whose insertion loss on the observed pair at the fundamental frequency is 15.7 dB ± 1.5 dB (assumes 7 m maximum)

- Compute the far-end integrated crosstalk noise (ICN) for each cable assembly
  - Denote σ_l as the far-end ICN for the low loss cable assembly
  - Denote σ_h as the far-end ICN for the high loss cable assembly
  - Utilize maximum peak differential output voltage and minimum rise and fall time in the calculation

- The transmitter under test is connected to one end of the reference cable assembly and the other end is connected to the cable assembly test fixture (that same fixture used to characterize the cable assembly)

Comments #127, #137 – Proposal (2 of 3)

- All lanes of the cable assembly test fixture are terminated in the reference impedance with the observed lane connected to the measuring instrument

- The observed lane of the transmitter under test sends PRBS9 while all other lanes send either scrambled idle or PRBS-31

- A fixed point on the PRBS9 output waveform is chosen and the RMS deviation from the mean voltage at this observation point is measured
  - It is recommended that the observation point and histogram window width be chosen such that the slope of the waveform within the window is close to zero
  - It is recommended that measurement is compensated for the noise in the measurement system

Comments #127, #137 – Proposal (3 of 3)

- For the low loss cable assembly, the measured RMS deviation shall be less than or equal to $\sigma_l + \mathrm{TBD}_1$

- For the high loss cable assembly, the measured RMS deviation shall be less than or equal to $\sigma_h + \mathrm{TBD}_2$

- TBD_1 and TBD_2 terms are added to account for package FEXT and other sources of transmitter noise not included in the integrated crosstalk noise calculation