IEEE 802.3dg Task Force

Getting to a less demanding Link Segment

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Background

- The suggested noise environment (see presentation “100BASE-T1L PSANEXT, PSAACR-F and RL Proposal”) and insertion loss limit (see presentation “100BASE-T1L Insertion Loss Proposal”) in combination lead to link segment definitions **close to the edge of what can be reasonably implemented using a DFE based PHY**.
- Due to the necessary increase of the **insertion loss limit for higher temperatures**, the overall system margin further **decreases by approx. 2.5 dB at 20 MHz** (about $f_{Nyquist}$ / 2).
- Therefore the goal of this presentation is to **provide a base for a discussion on how to allow for a higher system margin** by defining the noise environment depending on the insertion loss.
- The idea is **not to add an unnecessary burden for shorter link segments**, by **allowing a higher crosstalk** between the segments in this case, while on the other side **still allowing to run up to 500 m link segments using shielded AWG16 cables**.
- This would e.g. allow to place the **inline terminals directly next to each other for shorter link segments** and also add some additional margin for resonance effects seen at short link segments.
- **Long link segments** can be realized by **adding separation elements** between the terminal blocks/connectors to reduce the crosstalk at the unshielded connectors.

Application Background

- (Petro-)Chemical plants can be distinguished in different groups related to size and number of field devices:
  - *Small plants*
    - *Typically less than 2 000 field devices.*
    - *Typical trunk segment length less than* ***200 m****.*
  - *Mid-scale plants (typical chemical plant in Europe or the US)*
    - *Typically 2 000 to 4 000 field devices.*
    - *Typical trunk segment length between 200 to* ***300 m****, some few up to* ***400 m****.*
  - *Oil refinery or large LNG applications (typically in Europe or the US)*
    - *Typically 4 000 to 10 000 field devices.*
    - *Typical trunk segment length between 200 and* ***400 m****, some few up to* ***500 m****.*
  - *Large-scale plants (large petrochemical plants, large refineries, oil and gas infrastructure, mainly in Middle East and Asia)*
    - *More than 10 000 field devices, up to even 100 000 field devices (typically in the range 20 000 to 50 000 field devices).*
    - *Typically many 400 m to 800 m long trunk segments, some few segments even more than 1 000 m (supported by current fieldbus installations).*
    - *Most segments can be supported by having* ***500 m*** *trunk and 200 m spur segment length (which would allow for a maximum of 700 m in total).*
    - *Supported by current fieldbus applications, for 100BASE-T1L need for intermediate switches (for 10BASE-T1L most trunk segments will be supported).*

Application Background

- While for many small and mid-scale plants 400 m trunk segment lengths are working well, especially in the oil and gas industry large-scale plants are pretty common, especially in Middle East and Asia.

- Due to the very high number of nodes in these plants, even if the overall number of these applications is small compared to the number of typical mid-scale applications, a relevant amount of switches/field devices will be sold into such applications and thus needs support for 500 m trunk length (from an application perspective even significantly more, but limited by technical reasons).

- By providing IL adaptive crosstalk limits, for many applications simplified installation rules (e.g. up to 400 m segment length) can be applied, while still supporting segments up to 500 m in length (with reduced PSANEXT/PSAACR-F limits and a tighter controlled installation practice).

Length dependent Insertion Loss

- One possible way can be to define e.g. three different insertion loss limits at e.g. 20 MHz and modify the PSAFEXT and PSAACR-F limits, based on the insertion loss.

- On the next slide, the proposed IL limit curve (adapted for higher temperatures):

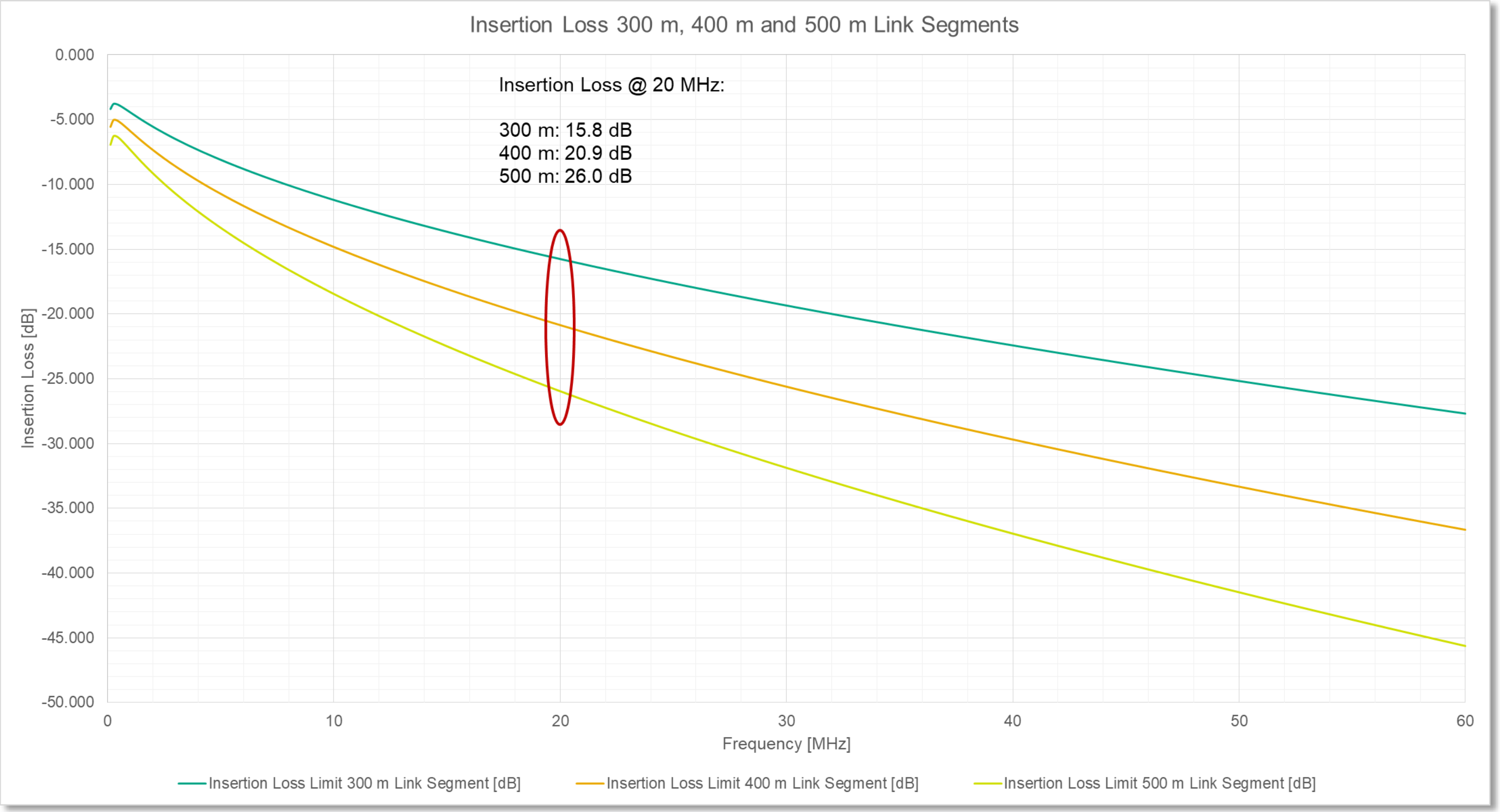
$$IL(f) = \left(5.42 \times \sqrt{f} + 0.044 \times f + \frac{1.76}{\sqrt{f}}\right) + 5 \times 0.02 \times \sqrt{f} \; with \; 0.1 \; MHz \leq f \leq 60 \; MHz$$

  is plotted for e.g. 300 m, 400 m, and 500 m AWG16 cables (equivalent to 240 m/320 m/400 m AWG18 cables) and 5 inline connectors.

- What can be seen is, that the insertion loss values @ 20 MHz are 15.8 dB (300 m), 20.9 dB (400 m) and 26 dB (500 m).
- So there is a difference in the insertion loss of approx. 5 dB @ 20 MHz per 100 m of cable.

- These limits (16 dB, 21 dB and 26 dB) can be used to adjust the crosstalk limits, based on the insertion loss, so that for shorter link segments a higher crosstalk is allowed and vice versa.

Length dependent Insertion Loss



Length dependent Crosstalk

- The increase of the insertion loss limit for higher temperatures, decreases the overall system margin by approx. 2.5 dB at 20 MHz (about $f_{Nyquist}$ / 2).
- Providing an additional margin of a further 2.5 dB in the noise environment would allow the currently suggested noise environment (PSANEXT and PSAACR-F limits) for a link segment length of up to 400 m (5 dB less insertion loss @ 20 MHz compared to the 500 m).
- For a 300 m long link segment, even 5 dB more crosstalk could be allowed, e.g. to allow for a higher resonance of the connector crosstalk or inline connectors with a higher crosstalk.
- For a 500 m long link segment, the crosstalk at the terminal blocks/connectors must be reduced by about 5 dB (which can be done by adding separation elements).

- This would allow for short (up to 300 m/240 m, AWG16/AWG18) link segments, even a relaxed installation practice (a little worse terminal blocks, less twisting of the wires), for medium length link segments (up to 400 m/320 m) a “normal” installation practice with non-separated terminal blocks can be used, while for long link segments (up to 500 m/400 m) special care to reduce the crosstalk by adding separation elements must be taken.

IL dependent PSANEXT/PSAACR-F Limits

- Suggested PSANEXT limits (depending on insertion loss):

$$PSANEXT\ [dB] = \begin{cases} 55 + 5 \times N & for\ 0.1\ MHz \le f < 10\ MHz \\ 55 + 5 \times N - 15 \times log_{10}\left(\frac{f}{10}\right) & for\ 10\ MHz \le f \le 60\ MHz \end{cases}$$

$$with\ N = \begin{cases} 0 & for\ 16\ dB < IL(20\ MHz) \\ 1 & for\ 16\ dB \le IL(20\ MHz) < 21\ dB \\ 2 & for\ 21\ dB \le IL(20\ MHz) \end{cases}$$

- Suggested PSAACR-F limit (depending on insertion loss):

$$PSAACR - F\ [dB] = \begin{cases} 55 + 5 \times N & for\ 0.1\ MHz \le f < 2\ MHz \\ 41 + 5 \times N - 20 \times log_{10}\left(\frac{f}{10}\right) & for\ 2\ MHz \le f \le 60\ MHz \end{cases}$$

$$with\ N = \begin{cases} 0 & for\ 16\ dB < IL(20\ MHz) \\ 1 & for\ 16\ dB \le IL(20\ MHz) < 21\ dB \\ 2 & for\ 21\ dB \le IL(20\ MHz) \end{cases}$$

Possibility to Relax Crosstalk Specification

- Presentations https://www.ieee802.org/3/dg/public/May_2022/zimmerman_3dg_01a_03_15_2023.pdf and https://www.ieee802.org/3/dg/public/May_2022/Tingting_3dg_01_15032023_v2.pdf perform a Salz SNR based margin analysis for the suggested link segment parameters.

- These presentations show a pretty high margin with the new PSANEXT and PSAACR-F noise models or even anticipated a 5 dB relaxed noise model compared to the originally suggested values in this presentation.

- Therefore it seems to be acceptable to relax the original crosstalk specification suggested in this presentation by 5 dB and still provide a reasonable margin for a DFE based PHY implementation.

- The next slide shows the PSANEXT and PSAACR-F with 5 dB relaxed limit lines (therefore it is expected that there is no need to add separation elements, even for the 500 m link segments, which simplifies the installation rules).

Summary (5 dB relaxed Limits)

- Suggested PSANEXT limits (depending on insertion loss):

$$PSANEXT\ [dB] = \begin{cases} 50 + 5 \times N & for\ 0.1\ MHz\ \leq f < 10\ MHz \\ 50 + 5 \times N - 15 \times log_{10}\left(\frac{f}{10}\right) & for\ 10\ MHz\ \leq f \leq 60\ MHz \end{cases}$$

$$with\ N = \begin{cases} 0 & for\ 16\ dB < IL(20\ MHz) \\ 1 & for\ 16\ dB \leq IL(20\ MHz) < 21\ dB \\ 2 & for\ 21\ dB\ \leq IL(20\ MHz) \end{cases}$$

- Suggested PSAACR-F limit (depending on insertion loss):

$$PSAACR-F\ [dB] = \begin{cases} 50\ + 5 \times N & for\ 0.1\ MHz \leq\ f < 2\ MHz \\ 36 + 5 \times N - 20 \times log_{10}\left(\frac{f}{10}\right) & for\ 2\ MHz\ \leq f \leq 60\ MHz \end{cases}$$

$$with\ N = \begin{cases} 0 & for\ 16\ dB < IL(20\ MHz) \\ 1 & for\ 16\ dB \leq IL(20\ MHz) < 21\ dB \\ 2 & for\ 21\ dB\ \leq IL(20\ MHz) \end{cases}$$

Thank you!