IEEE B802.3ap Ethernet Backplane - Channel Model ad-hoc

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1. Introduction

- A methodology for development of Ethernet backplane normative specification is proposed in this contribution. The method consists of developing normative specifications for the transmitter and the channel and an informative specification, the link budget. This methodology has been used for many existing 802.3ae clauses and is also used for 802.3aq.

- Normative specifications are required for the transmitter and the channel for interoperability. These specifications will include transmitter minimum and maximum output signal and transmit equalization (transmitter mask), jitter generation, return loss, and channel impulse response (including crosstalk).

- The parameter values included in this contribution (simulation results based on the channel data from Intel and Tyco) are needed to illustrate the methodology and are not intended to represent proposed normative values.

- If adopted, contributions will be required to define the actual parameters to be used in the normative specification and in the link budget.

- The methodology presented is based on NRZ signalling across the backplane. It can be modified for a different signalling technique.

2. Channel specification issues and proposed methodology

- Wide range of S parameters, depending on particular choices (length of traces on the line card and backplane, trace layer, and via length). The backplane implementation needs the freedom to make choices, assuming that the overall performance level is maintained.

- Using S parameters for normative specification is difficult. Efforts have been made to define limit cases (Tyco, IBM and Intel contributions).

- Time domain parameters and S parameters are correlated.

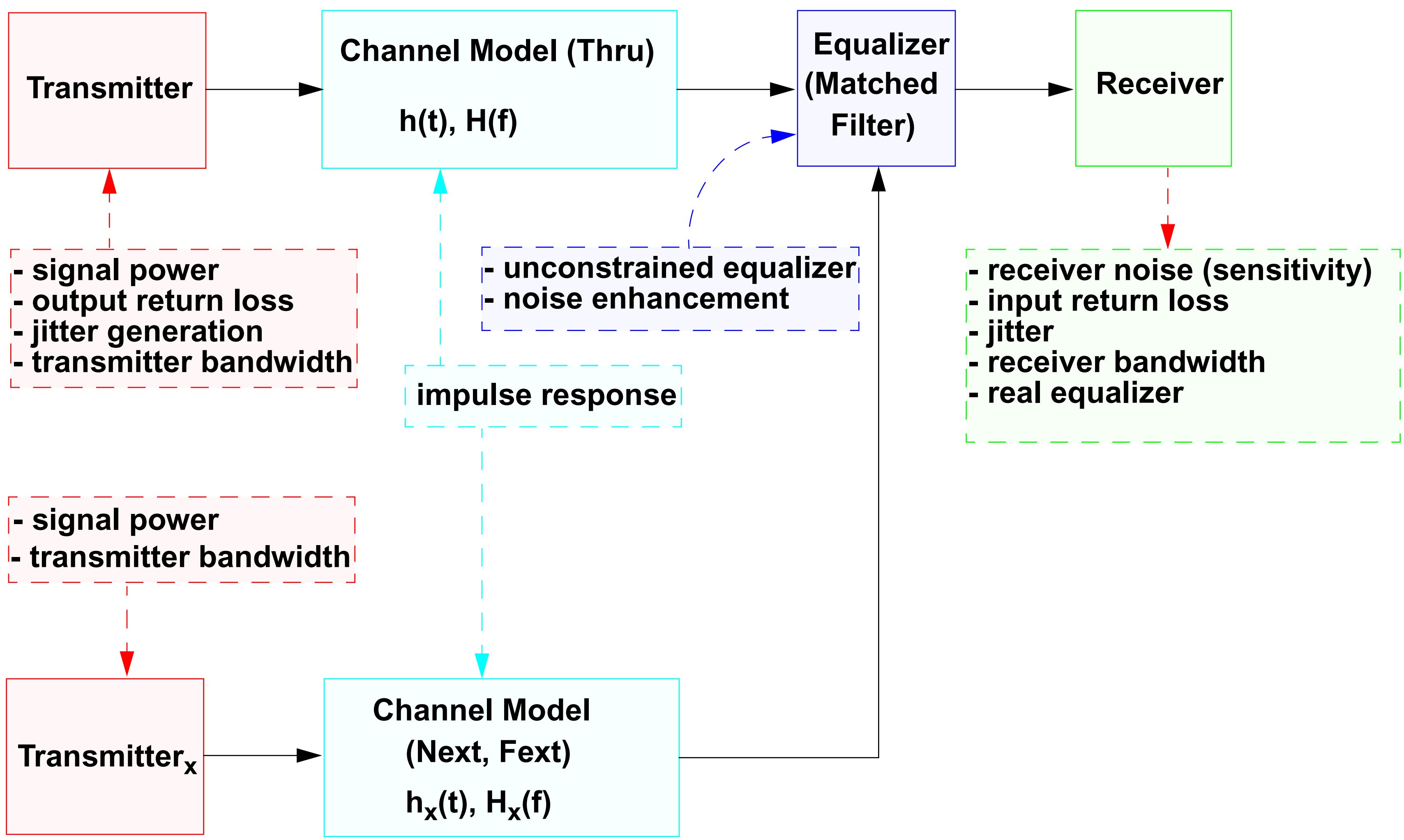
- Transmitter parameters (package, terminations, and jitter) will impact the channel response and link performance.

- Receiver parameters (receiver bandwidth, AC coupling capacitors, package, terminations and jitter) will impact the overall link performance.

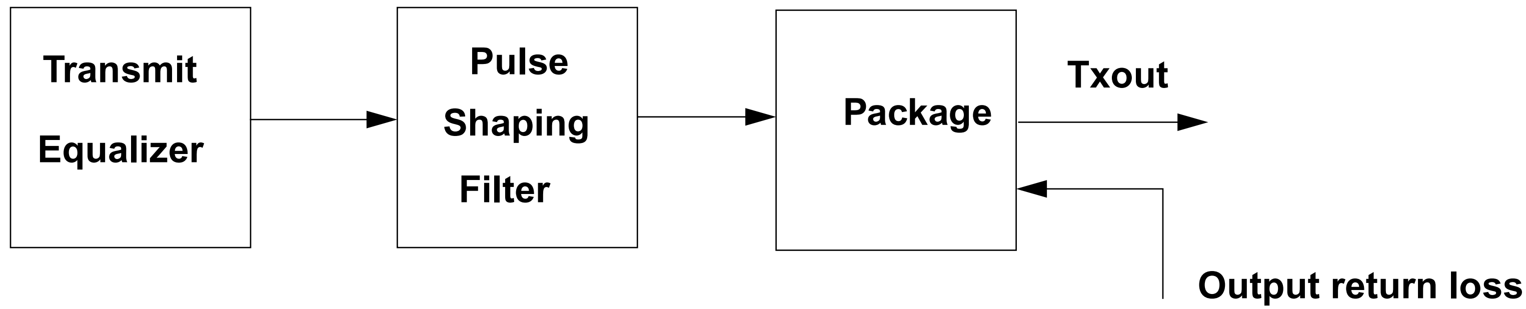
- The normative and informative specifications must be correlated to all these parameters and allow the designers to use the optimum solutions, and maintain the required level of performance.

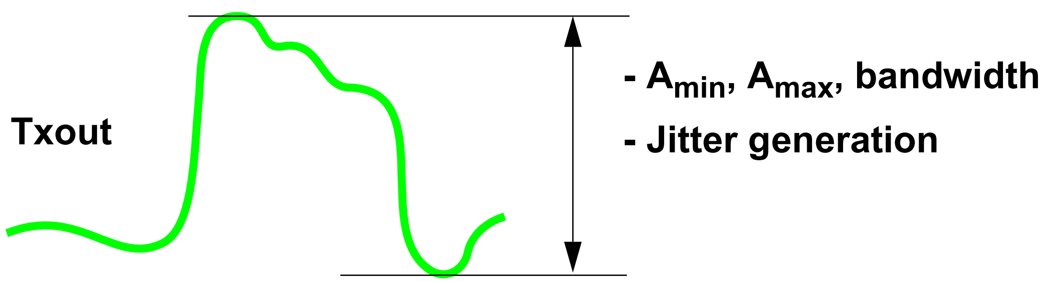
- The proposed methodology should allow the development of the conformance test and the interoperability test.

3. Link Configuration



4. Transmitter penalties



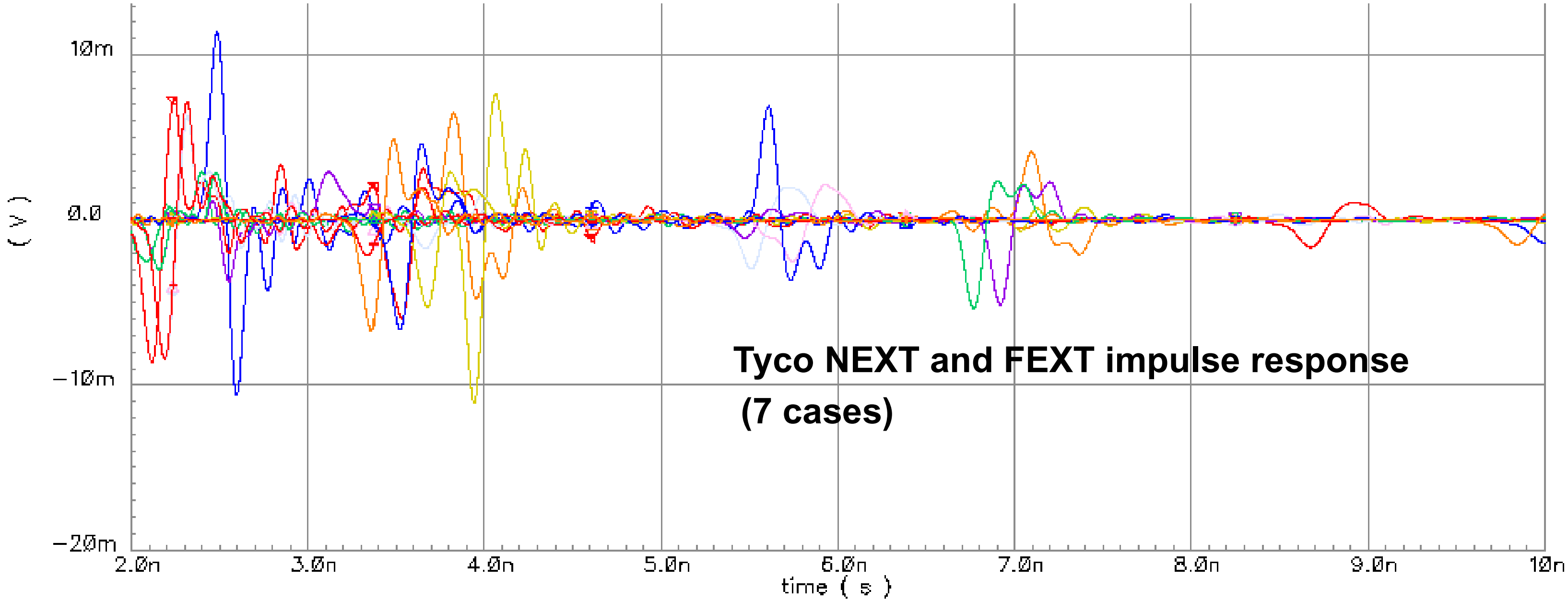


- Transmitter output power variation, maximum amplitude and maximum bandwidth (fast rise and fall times), minimum amplitude and slow rise and fall times, will affect the received signal amplitude, the SNR at the slicer input, and the crosstalk impulse amplitude.
- Transmitter output return loss will affect the received signal amplitude and the SNR at the slicer input.
- Transmitter jitter will reduce the effective horizontal eye opening and will require higher output power to maintain the SNR at the slicer input (non ideal sampling point).

5. Crosstalk penalty

- The link performance is affected by multiple crosstalk signals (NEXT and FEXT). The receive equalizer will increase the resulting noise power.

- Crosstalk noise will affect the received signal amplitude, is not stationary (pattern dependent) and can not be characterized by a specific (Gaussian like) distribution.



- One possible measure of the crosstalk impact on received signal amplitude is the power sum of the peak value crosstalk impulse responses:

$$V_{x,\,p} = \sqrt{\sum_j V^2_{peak(next)} + \sum_m V^2_{peak(fext)}}$$

- $V_{x,p}$ will reduce the equalized signal amplitude and the SNR at the slicer input.

6. Channel Metric

For equalized links, the power penalty (or allocation) can be used to ensure that the equalizer has enough input SNR for correct operation (Lee&Messerschmitt, Digital Communications, Chapter 10).

Assuming that the channel is characterized by the impulse response h(t), in the time domain, and H(f) in the frequency domain, the closed form integral expression for an ideal (unconstrained) Decision Feedback Equalizer (802.3aq cunningham_1_0104)

$$P_{DFE} = \exp\left(T \int_{\frac{-1}{2T}}^{\frac{1}{2T}} \ln\left(\left|H(f)\right|^2\right) df \right)$$

A similar expression for P_{DFE}, including the allowance for the maximum acceptable BER, can be used as a channel metric (802.3aq bhoja_1_0704).

The real implementations (constrained equalizers) will require more power (2 or 3 dB) to maintain the SNR at the slicer input. Additional margins may be added as dynamic adaptation allowance.

For the link budget calculations, I will assume that the maximum power penalty (P_{DFE}) for the backplane impulse response is 7 dB (power, or signal amplitude).

7. Receiver

- The receiver consists of a real equalizer, the slicer and the CDR (clock and data recovery). All these components will contribute to the link performance.

- Input referenced noise (receiver noise floor) will set the minimum required signal for achieving the desired BER (receiver sensitivity).

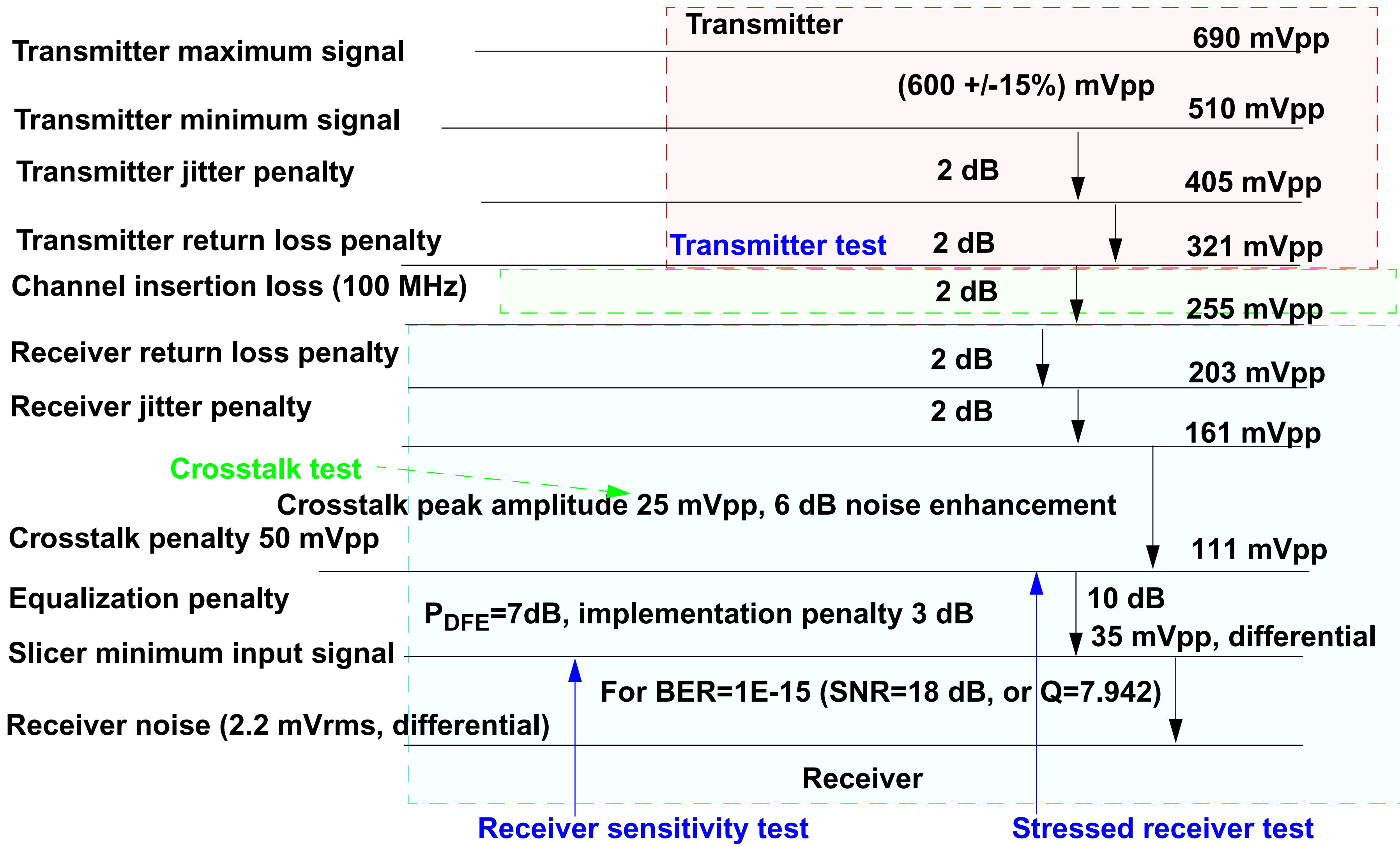
- The real (non ideal) equalizer will recover the original signal with a certain error and will increase the noise power (noise enhancement).

- Receiver input return loss will impact the actual received signal power and will increase the non-stationary noise level due to reflections.

- Receiver bandwidth will affect the received signal power and the noise power. I have assumed the receiver bandwidth equivalent to a 4-th order BT LPF 7.5 GHz.

- The recovered clock will have jitter components and will result in a reduction of the actual signal level (non ideal sampling point) at the slicer input.

8. Link Budget



9. Summary

- The proposed methodology is based on channel impulse response and allows the backplane designer (backplane and the two cards) to select the optimum solution and maintain the overall system requirements.

- Normative specifications and compliance test methodology can be developed for all link components (transmitter, channel, and receiver).

- A link budget, informative specification, can be developed to support the normative specifications and evaluate the overall system performance.

- The methodology proposed in this contribution assumes NRZ type signalling and can be modified for other signalling techniques. All numbers used in the link budget are used to explain the method and are not intended to be normative values.

- If adopted, contributions will be needed to set the normative parameters, transmitter output mask, and interoperability test.