# 10 Mb/s Single Twisted Pair Ethernet
## 10BASE-T1L Noise Test

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# Alien Noise Levels for 10BASE-T1L

- In the actual link segment definition in 146.7.2 the coupling parameters between 10BASE-T1L link segments are defined as:

$$PSANEXT(f) \geq 37.5\ dB - 17\ dB \cdot log_{10}\left(\frac{\frac{f}{MHz}}{20}\right)\ for\ 0.1\ MHz \leq f \leq 20\ MHz$$

$$PSAFEXT(f) \geq 38\ dB - 18\ dB \cdot log_{10}\left(\frac{\frac{f}{MHz}}{20}\right)\ for\ 0.1\ MHz \leq f \leq 20\ MHz$$

- As PSAFEXT instead of the power sum of the EL-FEXT is being used, the PSAFEXT value already includes the insertion loss of the link segment between the far end alien noise disturber and the near end receiver.

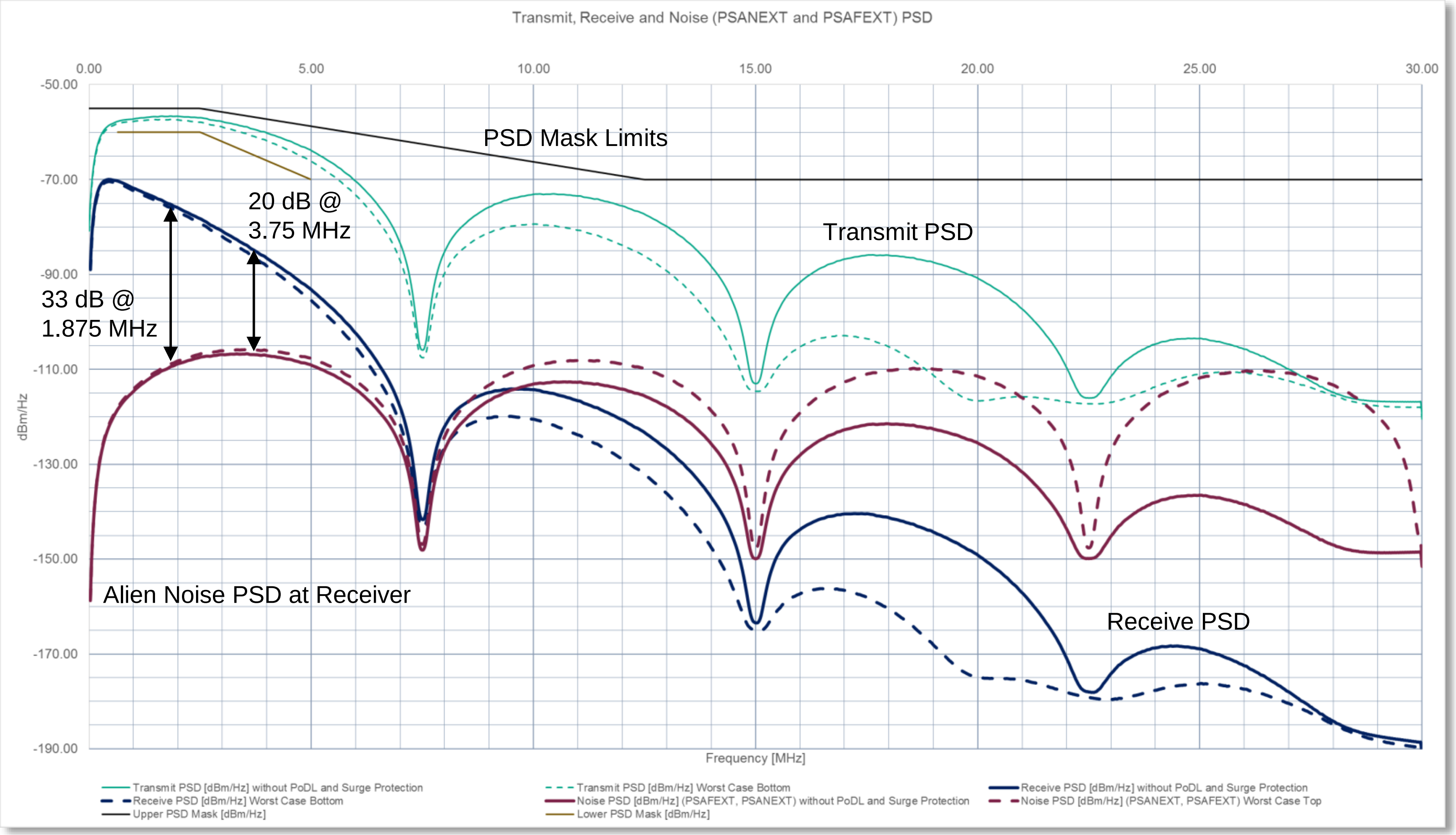
- Summing up the PSANEXT and PSAFEXT values to calculate the summed alien noise crosstalk at one end of the link segment will lead to:

$$PSAXT(f) \geq -10 \cdot log_{10}\left(10^{-\frac{PSANEXT(f)}{10}} + 10^{-\frac{PSAFEXT(f)}{10}}\right)$$

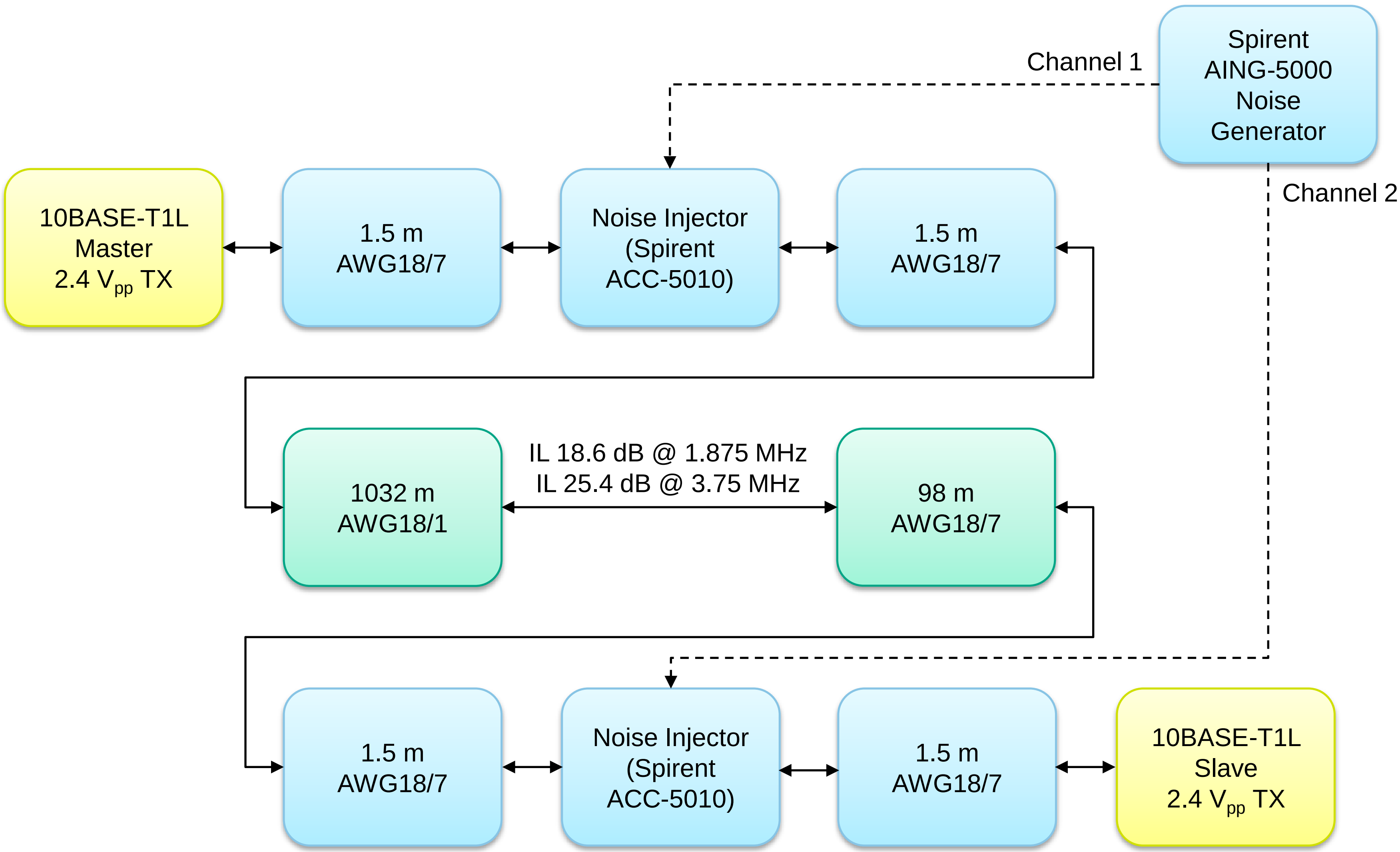
- Multiplying the summed alien noise crosstalk with the PSD of a 10BASE-T1L transmitter calculates the PSD of the crosstalk noise coming from other 10BASE-T1L segments.

# Alien Noise Levels for 10BASE-T1L

- The green curves show the transmit PSDs.
- The blue curves show the PSDs at the receiver side after running over the 1000 m link segment with the frequency dependent insertion loss.
- The red curves show the alien noise PSDs at the receiver side.



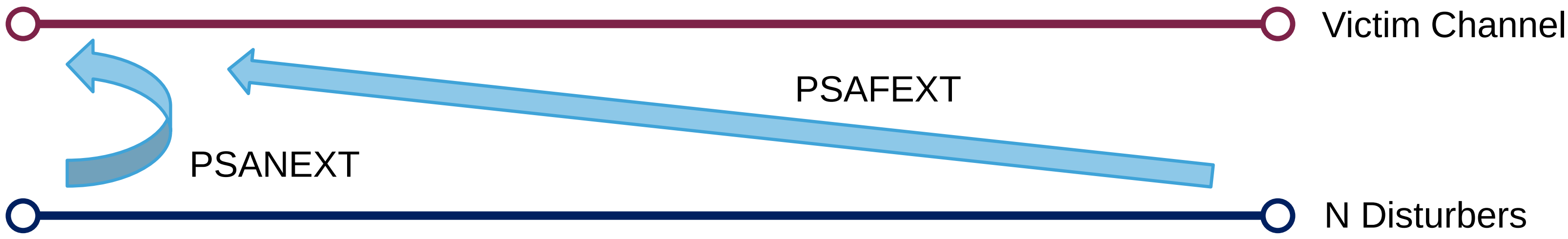
# Noise Test Setup



# Noise Test Setup

- As transmit PSD for the calculation of the noise levels the „worst-case top" curve, as shown in presentation http://www.ieee802.org/3/cg/public/Jan2018/Graber_3cg_02_0118.pdf (10BASE-T1L PSD Mask, page 10) is being used.

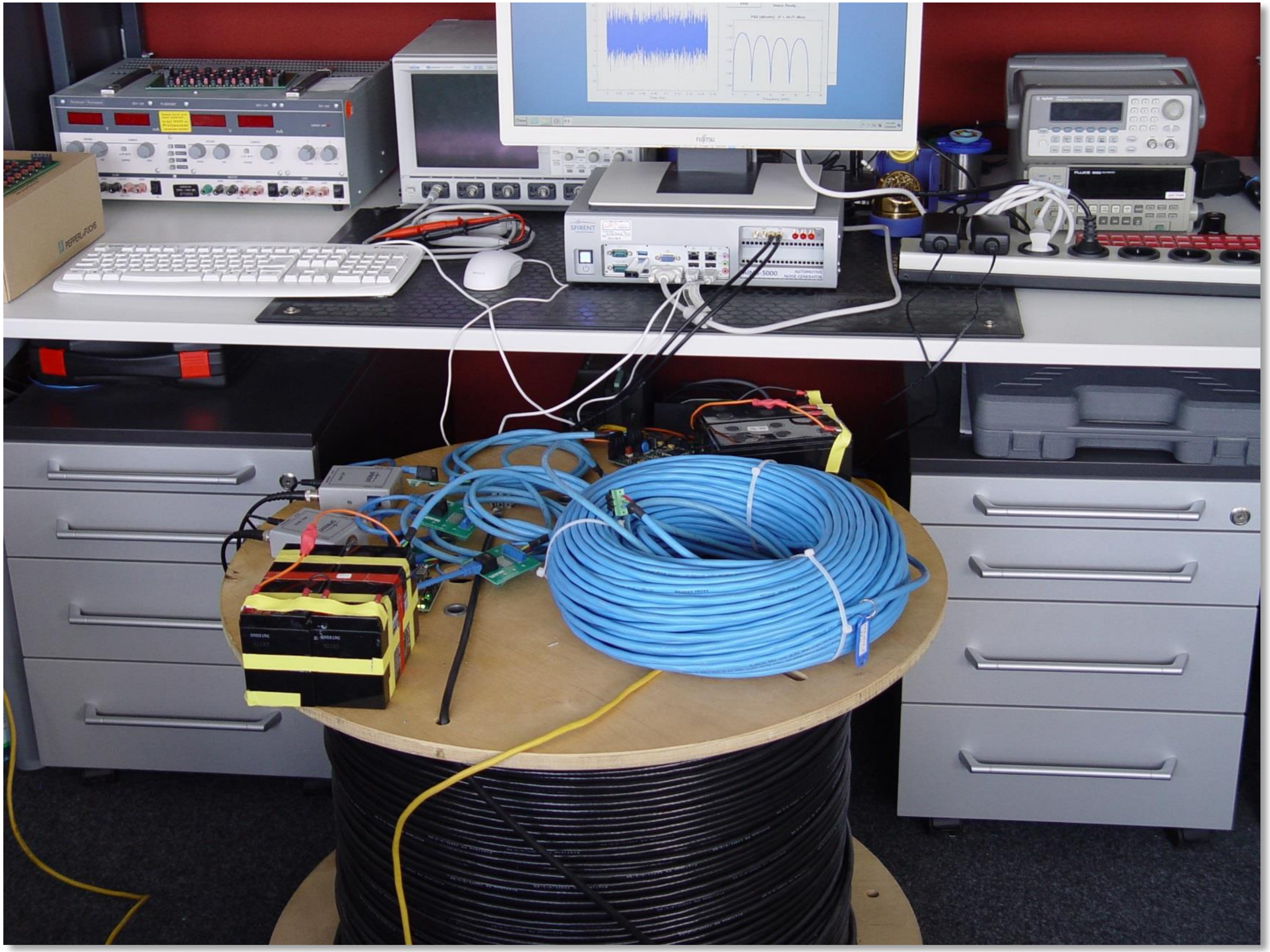
- The noise can be injected on channel 1 simulating the PSANEXT and PSAFEXT for the master PHY side.
- Alternatively the noise can be injected on channel 2 simulating the PSANEXT and PSAFEXT for the slave PHY side.




- The insertion loss of the link segment is chosen to closely reflect the specified insertion loss at Nyquist frequency for a 1000 m link segment (25.4 dB IL @ 3.75 MHz).

- On both ends of the link segment a FPGA based evaluation board is being connected (see presentation http://www.ieee802.org/3/cg/public/May2017/Graber_3cg_07_0517.pdf for more details).

# Noise Test Setup



# Noise Measurements

- As the correct transmit data stream is not known by the receiver at the other side of the link segment, and there is no forward error correction being implemented, only an indirect detection of the bit errors is possible at the moment (additionally to the possibility to run Ethernet packets over the link, e.g. using pings, but then the measurement time will have to be increased due to low link utilization using free ping software).
- The FPGA based evaluation board allows to read back the maximum slicer error, compared to the decision levels of $\pm 0.5$ and also counts the number of events every time a slicer error of more than 0.5 has been detected.
- This allows to detect slicer input values, with absolute values greater than 1.5.
- Assuming that the probability for such an event is the same as a wrong interpretation of a $\pm 1$ as 0 and also the same as a wrong interpretation of a 0 as a +1 or a -1, then the error counter value multiplied with two reflects the number of receive bit errors as long as the number of received bits is large compared to the number of bit error events.
- If zero errors have been detected, then also no 4B3T disparity errors have be observed, which is consistent to the zero detected bit errors.
- The test time was approx. 300 seconds for each row, which provides a 95 % confidence level for a bit error ratio of $10^{-9}$ as long as no bit errors have been received.

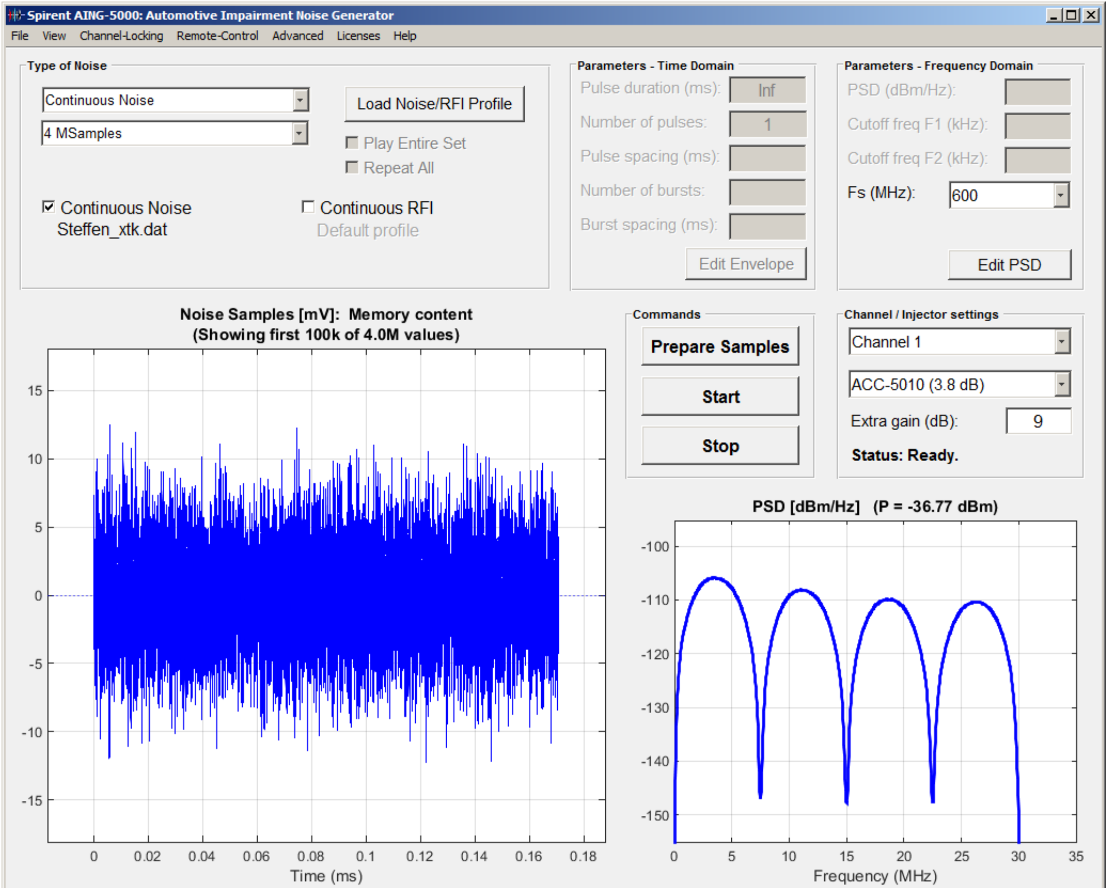
# Noise Measurements

| Noise Margin | Slicer Event Counter | Equivalent Error Count Value | Max. Error Value |
|---|---|---|---|
| 9.0 dB | 0 | 0 | 0.4021 |
| 9.5 dB | 0 | 0 | 0.4517 |
| 10.0 dB | 0 | 0 | 0.4592 |
| 10.5 dB | 0 | 0 | 0.4763 |
| 11.0 dB | 0 | 0 | 0.4976 |
| 11.5 dB | 0 | 0 | 0.3982 *) |
| 12.0 dB | 0 | 0 | 0.4211 *) |
| 12.5 dB | 0 | 0 | 0.4419 *) |
| 13.0 dB | 0 | 0 | 0.4463 *) |
| 13.5 dB | 0 | 0 | 0.4867 *) |
| 14.0 dB | 2 | 4 | 0.6538 *) |
| 14.5 dB | 203 | 406 | 1.3931 *) |
| 15.0 dB | 3556 | 7112 | 1.8396 *) |

- The numbers above have to be compared to the number of transmitted bits of $3 \cdot 10^9$.
- The maximum error value in the table above is the maximum difference between the slicer input and the decision levels of the slicer during the 300 second period of time.

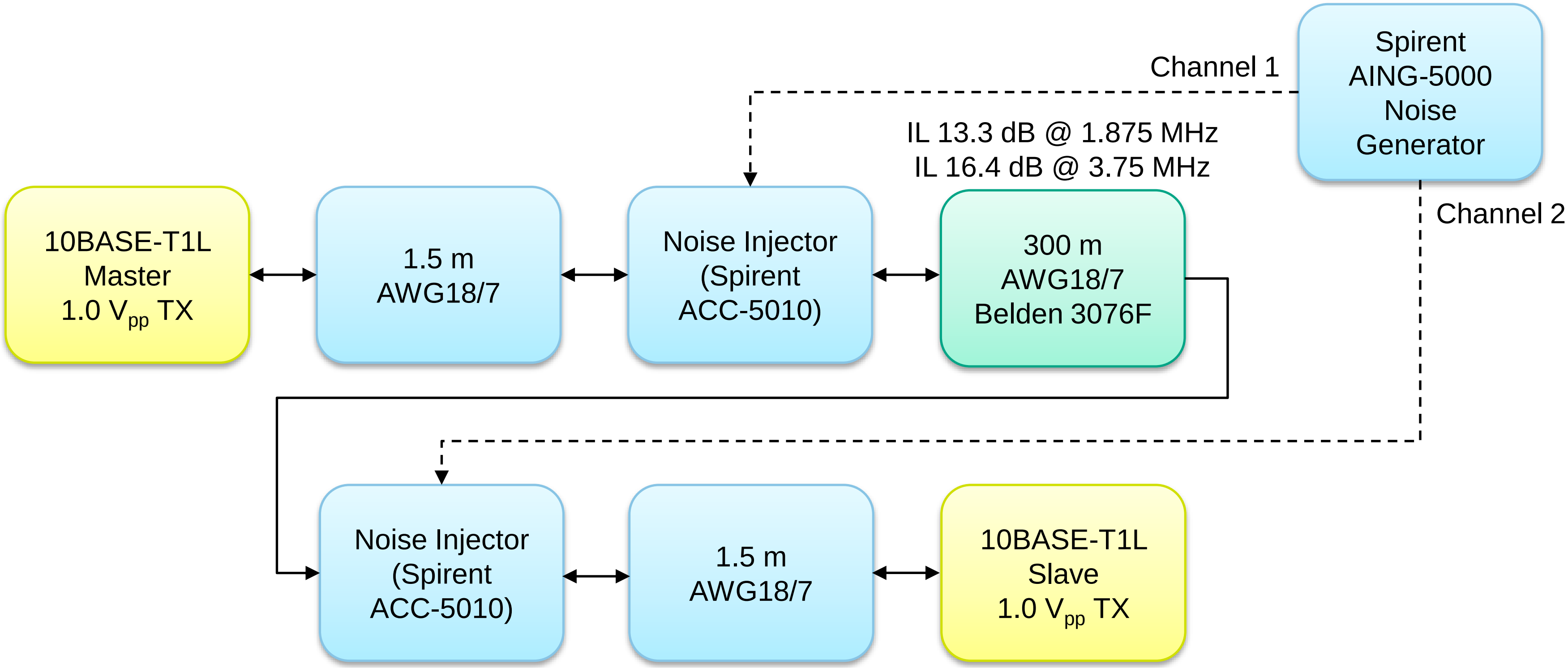
*) For noise levels of more than 11 dB above the specified alien noise levels in 802.3cg D1.1 the filter training has been disabled.

# Noise Measurements




- Tests show a margin of **9 dB** relative to the specified alien crosstalk noise levels in 802.3cg D1.1 for measurement times longer than 3 hours, which is equivalent to a BER of $10^{-10}$ with a confidence level of about 99.99 %.
- A set-up noise margin of 9.5 dB has resulted in two receive errors within a 3 hours time frame.
- The measurement was done using a transmit level of 2.4 $V_{pp}$.

# Link Segment Length Estimation for 1.0 $V_{pp}$




- The alien noise levels injected by the Spirent noise generator are still the levels equivalent to a 2.4 $V_{pp}$ transmit amplitude of the disturbing PHYs as for the former tests.
- Two FPGA based evaluation boards have been modified for a transmit amplitude of 1 $V_{pp}$ and being connected to above shown link segment, mainly consisting of 300 m Belden 3076F cable.
- The resulting noise margin is **6 dB** for a long time measurement (> 1800 s).
- The measured insertion loss of the link segment at 1.875 MHz is 13.3 dB, the measured insertion loss of the link segment at 3.75 MHz is 16.4 dB.

# Link Segment Length Estimation for 1.0 $V_{pp}$

- Calculating the resulting link segment length according to the IL limits specified in 802.3cg D1.1 (using the mean square pulse loss, which can be approximately calculated at ½ Nyquist frequency or 1.875 MHz) for a noise margin of 6 dB leads to:

$$\frac{13.3\ dB - 10 \cdot 0.02 \cdot \sqrt{1.875\ MHz}}{1.23 \cdot \sqrt{1.875\ MHz} + 0.01 \cdot 1.875\ MHz + \frac{0.2}{\sqrt{1.875\ MHz}}} \cdot 100\ m = 704\ m$$

- Taking a margin of 9 dB as for the 2.4 $V_{pp}$ transmit amplitude into account this would lead to:

$$\frac{13.3\ dB - (9\ dB\ - 6\ dB) - 10 \cdot 0.02 \cdot \sqrt{1.875\ MHz}}{1.23 \cdot \sqrt{1.875\ MHz} + 0.01 \cdot 1.875\ MHz + \frac{0.2}{\sqrt{1.875\ MHz}}} \cdot 100\ m = 542\ m$$

- The resulting maximum link segment length according to the definitions of clause 146.7 in 802.3cg D1.1 is approximately 700 m for a margin of 6 dB and approximately 540 m for a margin of 9 dB relative to the specified alien crosstalk noise levels in 802.3cg D1.1.

# Summary

- The used test method allows a good reproducibility of the test results by providing wide control over the crosstalk coupling properties, compared to e.g. using a second master PHY being connected to the link segment using a resistive divider as this is done in other Ethernet standards.
- Knowing the transmit PSD of the transmitter and the noise coupling parameters from the link segment definition, the created noise patterns can be directly coupled onto the link segment without the need of crosstalk testing using different link segments running in parallel.
- Being able to set an additional extra gain factor provides an easy way determining the system margin as shown on the previous slides.
- Tests with other cable configurations (not only the 1000 m link segment) can be easily added to test for a different link segment length or to also test with other cable constructions (such as different wire gauges).
- Adding some stationary background noise (e.g. in the power supply frequency range) to the used noise patterns could make the noise profile yet more realistic in future tests.
- For PHYs using a reduced transmit amplitude depending on the intended noise margin a link segment length between 540 m (approx. 9 dB margin) and 700 m (approx. 6 dB margin) seems to be possible.

# Next Steps/Questions

- We need to decide as a group, if the white noise test specified in 802.3cg D1.1 is sufficient, or if there is need to specify an additional alien noise test as shown in this presentation (e.g. as an alternative for the test using a second master PHY being connected to the link segment over a resistive divider to simulate an alien disturber, as it is used in some other Ethernet standards).

- Do we still see the need for testing impulsive noise in industrial/automotive applications or is there a common view, that testing with white noise or alien noise as it is done in other Ethernet standards is sufficient?

- Are there any further requirements related to application specific noise testing?

# Thank You

# Backup Slides

# BER Measurement Confidence Level