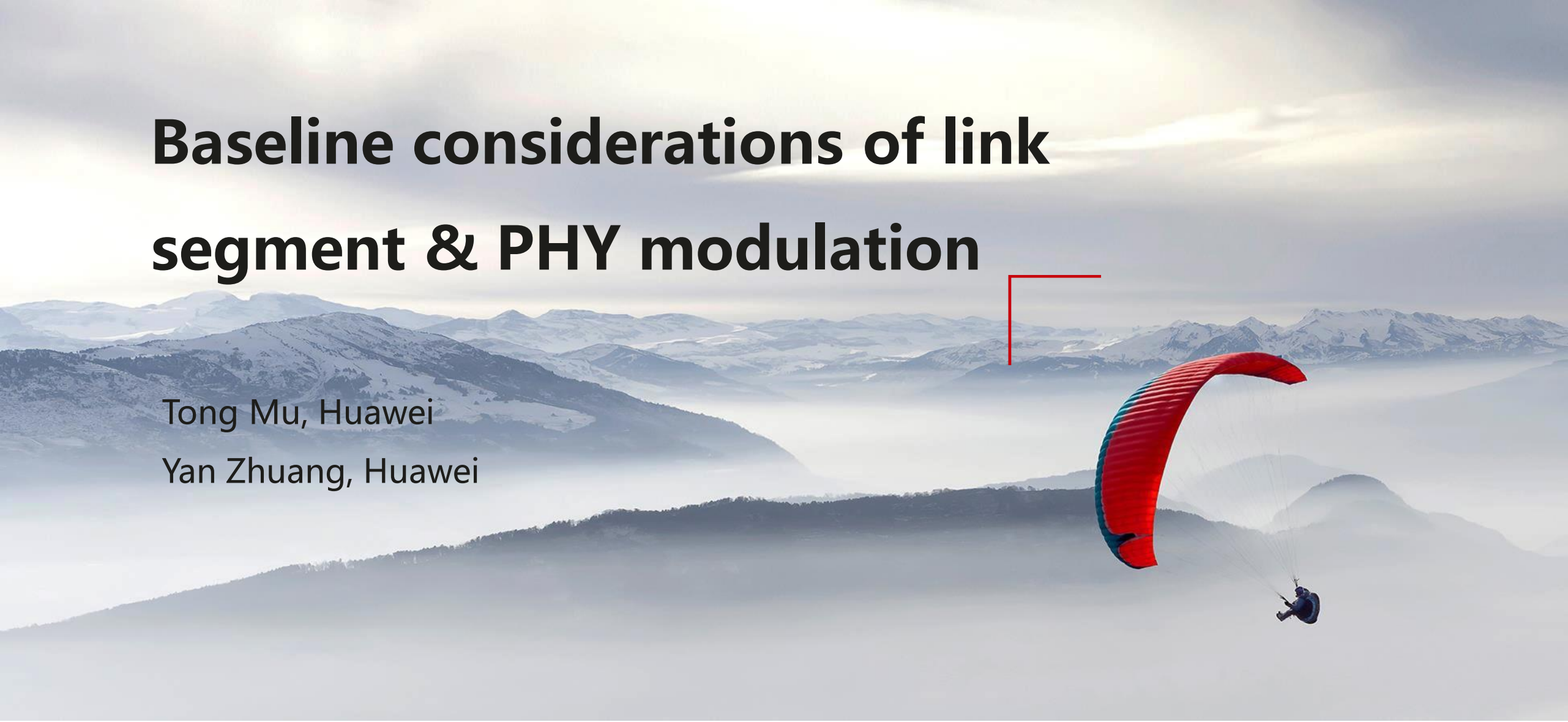
Baseline considerations of link segment & PHY modulation



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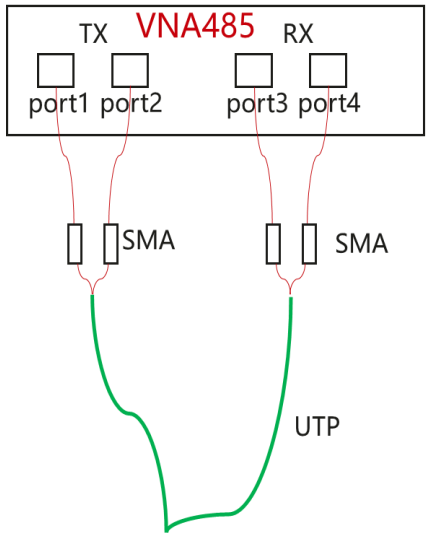
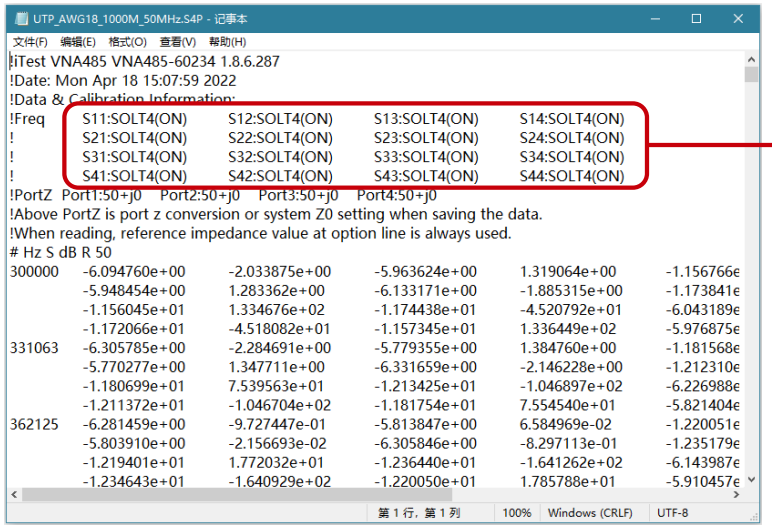
Outline

- Show measurement results of link segments @500m AWG18 and @200m AWG24 for 100BASE-T1L and provide baseline for the Trunk IL.
- Provide simulation and comparison between different modulations and suggest PAM3 as the choice for 100BASE-T1L.
- Consideration on single pair PoE for intrinsically safe operation.

1. Link segment

Link segment settings





$$S = \begin{pmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{pmatrix} \quad S_M = \begin{pmatrix} Sdd11 & Sdc11 & Sdd12 & Sdc12 \\ Scd11 & Scc11 & Scd12 & Scc12 \\ Sdd21 & Sdc21 & Sdd22 & Sdc22 \\ Scd21 & Scc21 & Scd22 & Scc22 \end{pmatrix}$$

$$\begin{pmatrix} \frac{S_{11}-S_{12}-S_{21}+S_{22}}{2} & \frac{S_{11}+S_{12}-S_{21}-S_{22}}{2} & \frac{S_{13}-S_{14}-S_{23}+S_{24}}{2} & \frac{S_{13}+S_{14}-S_{23}-S_{24}}{2} \\ \frac{S_{11}-S_{12}+S_{21}-S_{22}}{2} & \frac{S_{11}+S_{12}+S_{21}+S_{22}}{2} & \frac{S_{13}-S_{14}+S_{23}-S_{24}}{2} & \frac{S_{13}+S_{14}+S_{23}+S_{24}}{2} \\ \frac{S_{31}-S_{32}-S_{41}+S_{42}}{2} & \frac{S_{31}+S_{32}-S_{41}-S_{42}}{2} & \frac{S_{33}-S_{34}-S_{43}+S_{44}}{2} & \frac{S_{33}+S_{34}-S_{43}-S_{44}}{2} \\ \frac{S_{31}-S_{32}+S_{41}-S_{42}}{2} & \frac{S_{31}+S_{32}+S_{41}+S_{42}}{2} & \frac{S_{33}-S_{34}+S_{43}-S_{44}}{2} & \frac{S_{33}+S_{34}+S_{43}+S_{44}}{2} \end{pmatrix}$$

- We use customized 1000m AWG18 UTP (for trunk) and 200m AWG24 UTP (for spur) for the measurements
- No inline connectors are included
- Use VNA to measure the four-port network S parameters (each port has been calibrated to 50Ω)
- Measurement frequency range is 300KHz~50MHz
- Cable IL and RL are derived from .S4P file

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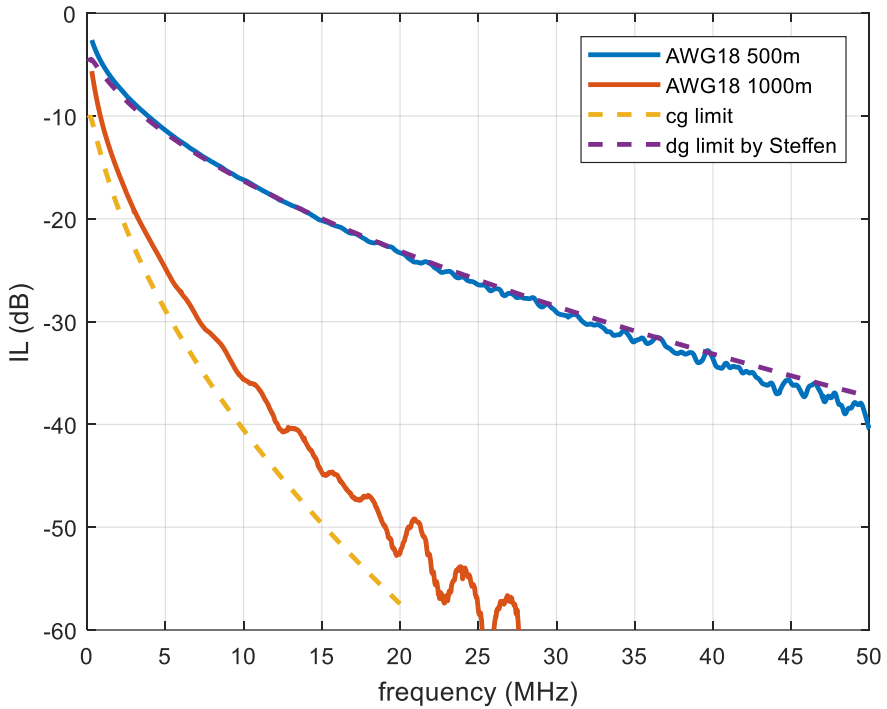
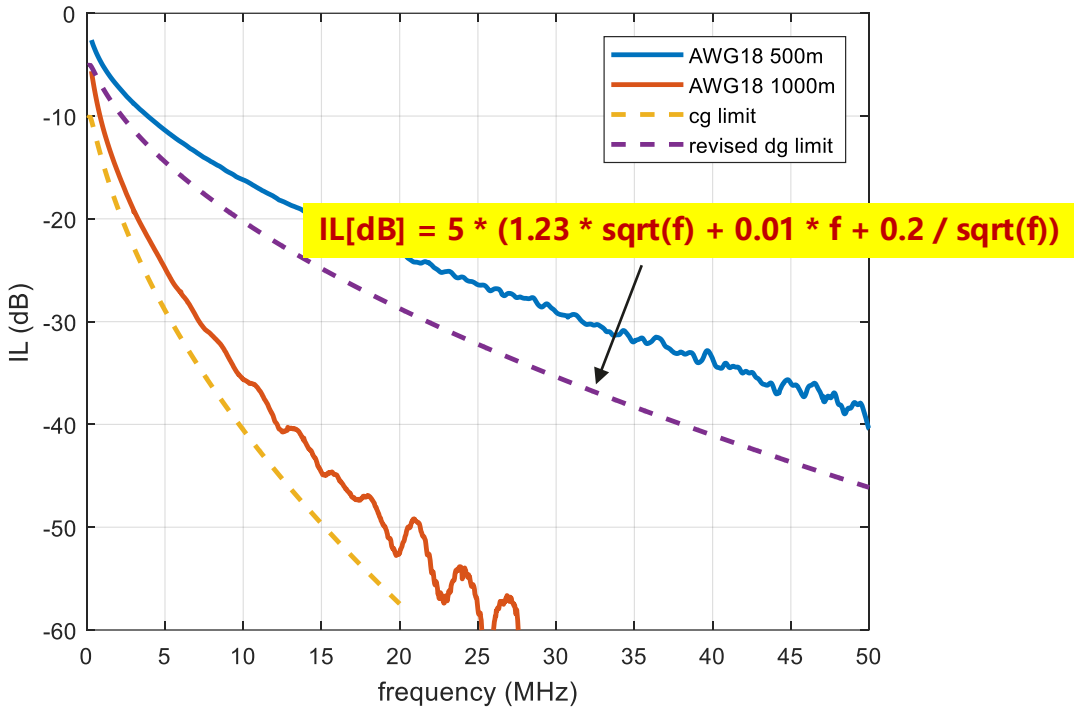
Trunk segment IL@500m AWG18



- The measured IL of AWG18 1000m cable meets the cg limit
- The measured IL of AWG18 500m cable does not meet the limit proposed in graber_3dg_01_08302022, which is estimated based on powering cable loss



- A revised IL limit proposal is given by changing the factor of AWG16 to AWG18 at the length of 500m

- 10BASE-T1L defines the IL limit based on signal transmission feasibility.
- 10Base-T1L provides a transmission distance of 1000m with AWG 18 while if it works with class 15, the distance is reduced to around 170m. Hence, it would be the choice of deployment to decide their power level and its corresponding distance.
- As such, using AWG18 500m as the reference for IL limit might be more reasonable.

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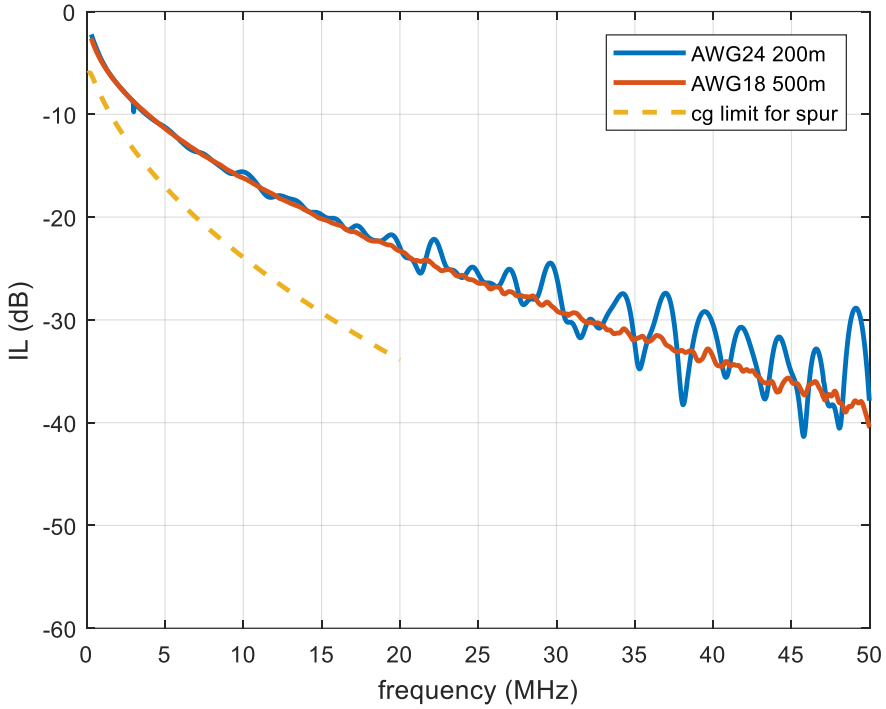
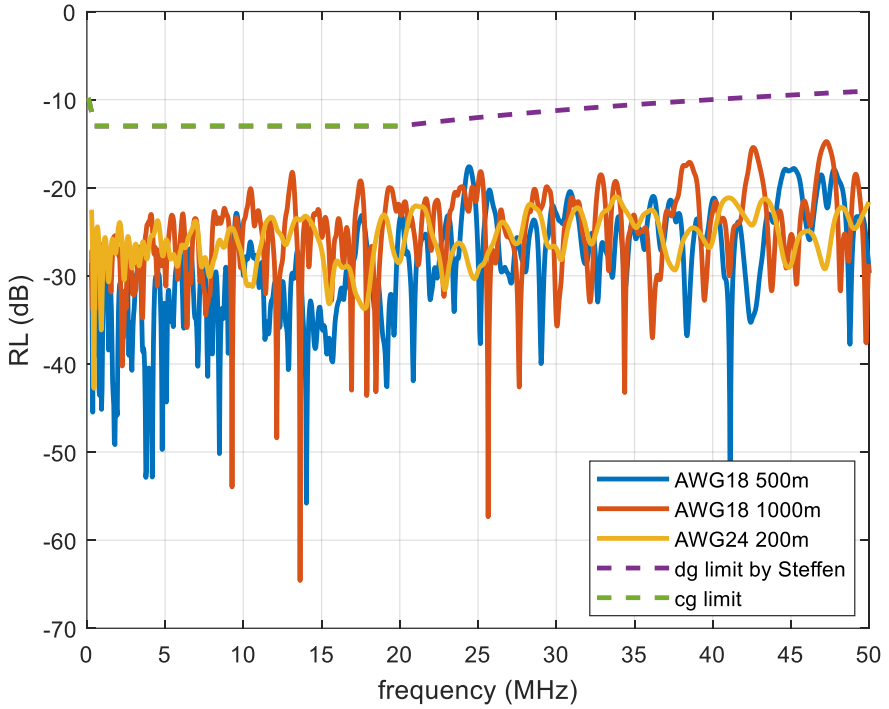
Spur segment IL@200m AWG24 and overall RL





- The measured IL of AWG24 200m cable meets the cg limit
- The AWG24 200m cable has similar IL to the AWG18 500m cable within 20MHz, but has some fluctuations in higher band due to reflections in measurement

- The measured RL of AWG18 1000m cable meets the cg limit
- The overall RL get worse at higher frequencies, so a non-flat limit seems reasonable
- Inline connectors are not included

Shall we consider 100BASE-T1L used at Spur?

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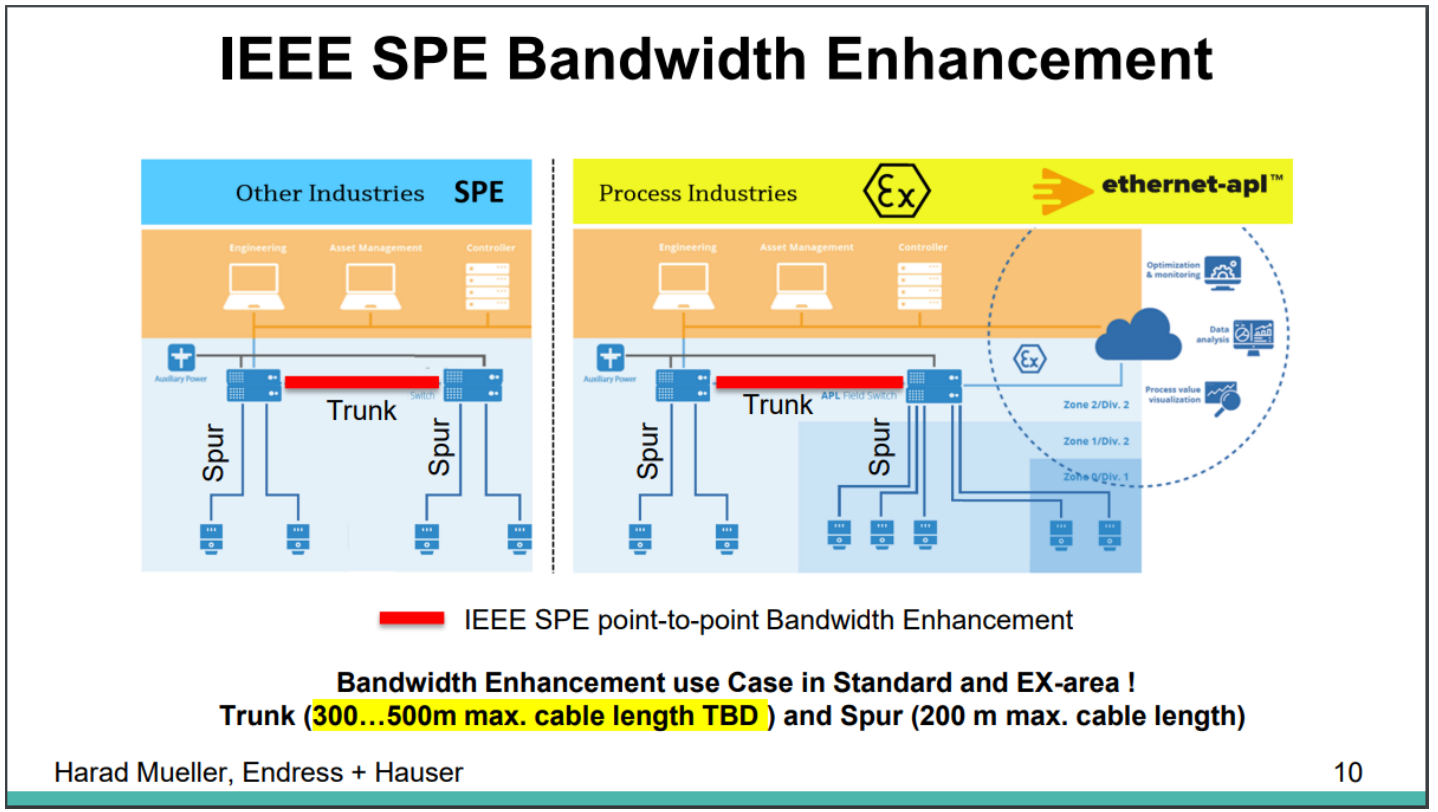
Does 802.3dg consider to cover Spur?



Options for Spur usage:

- Option1: No, 100Mbps used only for the Trunk segement.
- Option2: Yes, use the same IL and TX power as Trunk, but may have intrinsically safe issues.
- Option3: Yes, but define better IL and lower TX power than Trunk, similar to 802.3cg.

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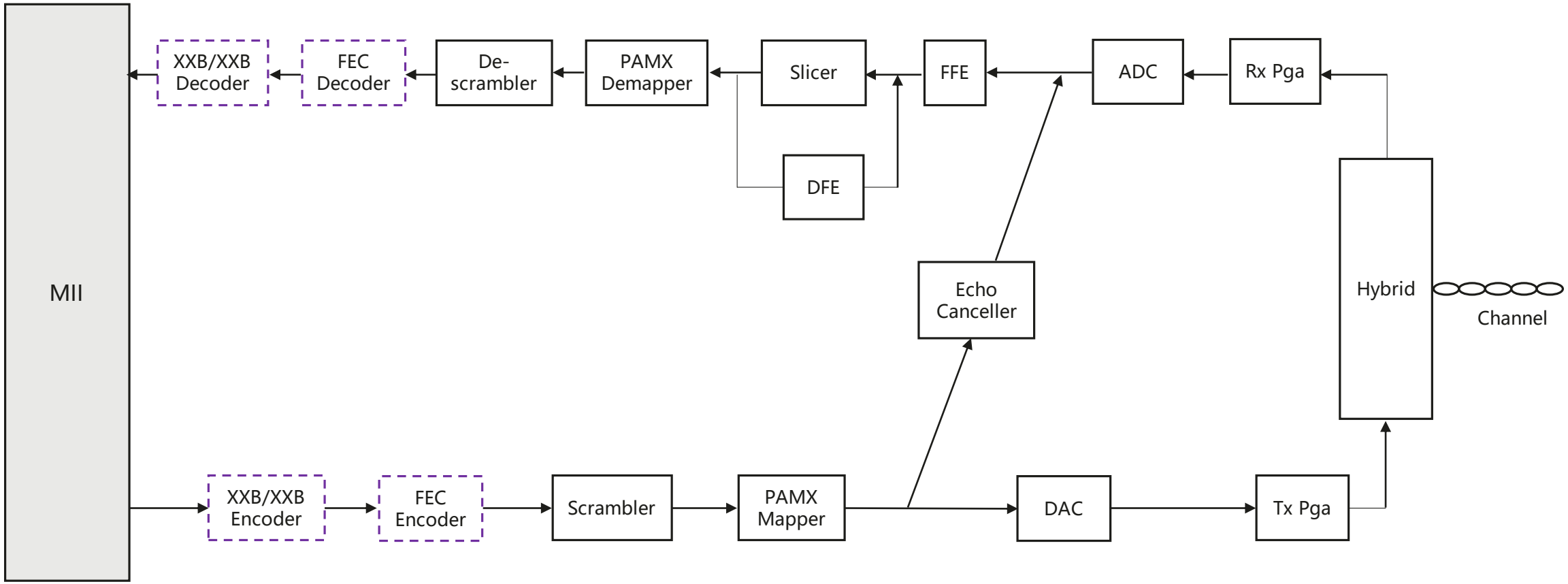
2. PHY

PHY architecture for 100BASE-T1L simulation



- Show example PHY block diagram used for Matlab simulation, similar to 802.3cg model
- To verify the feasibility of 100M@500m AWG18 channel, and evaluate different modulation performance

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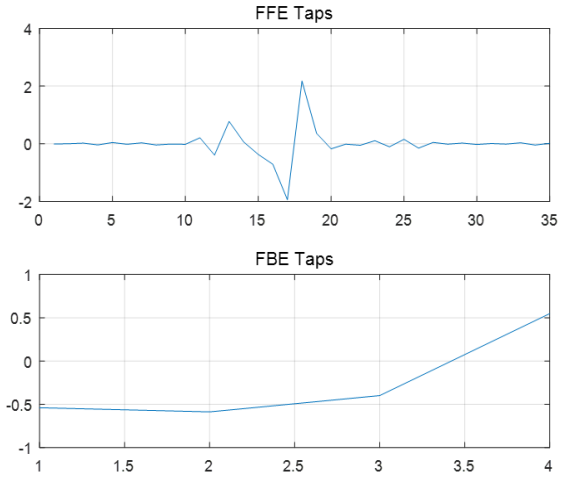
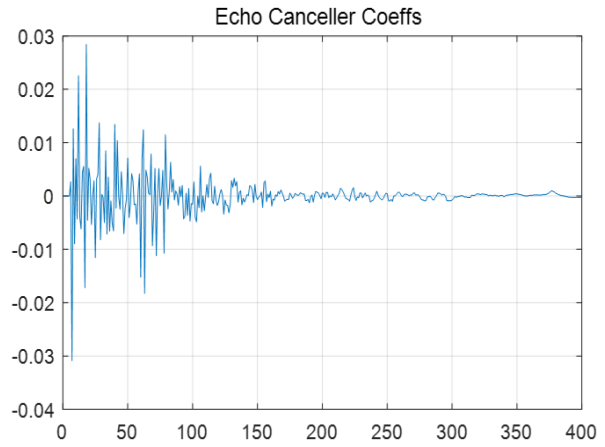
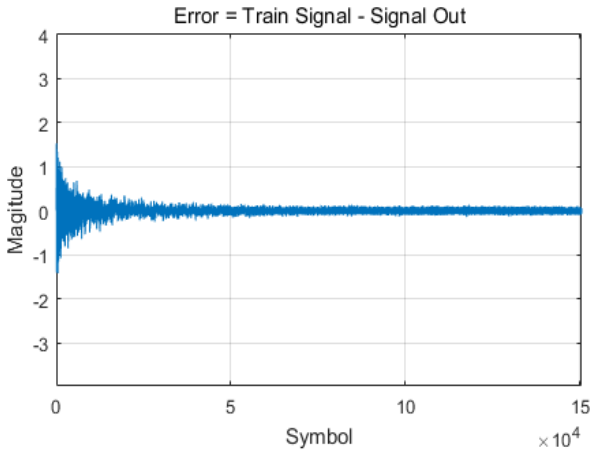
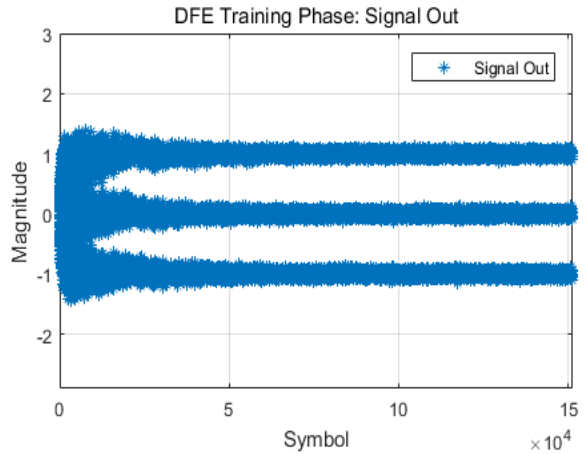
PHY simulation setup

- Overhead: 20%, PAMn symbol rate is estimated as 100/log2(n)*1.2 (MBd), n = 2, 3, 4, 5
- Transmit power: 9dBm (2.4Vpp mode)
- Channel: measured AWG18 500m cable, connectors and hybrid are not considered yet
- Noise: -130dBm/Hz AWGN
- FFE tap: 35, DFE tap: 4, EC tap: 400









Some output results (PAM3 example)

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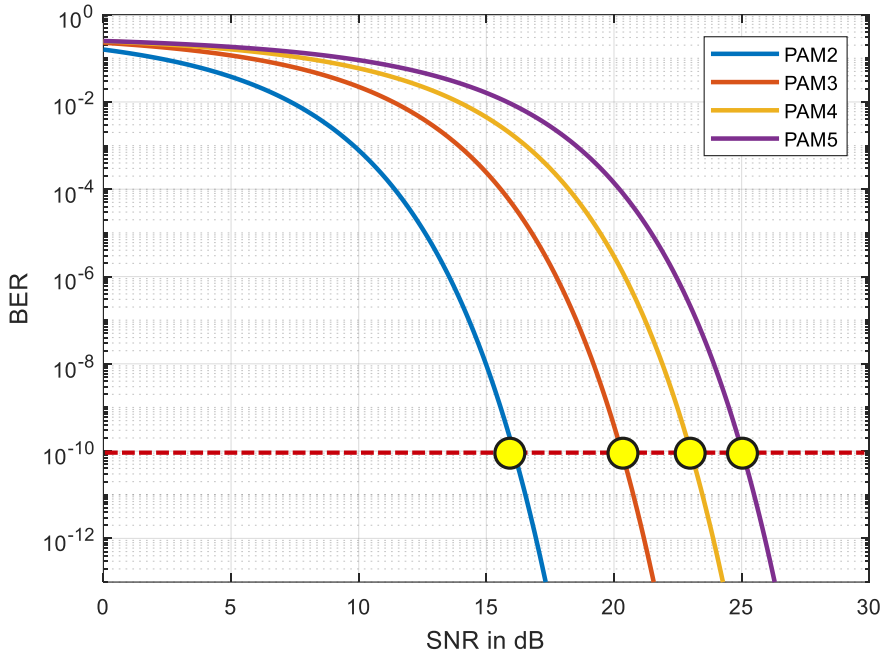
Suggest PAM3 for 100BASE-T1L

Simulated system SNR for different PAM

Case	SNR/dB	Requirement/dB	Margin/dB
PAM2	21.6	16.1	5.5
PAM3	29.0	20.4	8.6
PAM4	30.2	23.1	7.1
PAM5	31.1	25.1	6.0

Required SNR for BER@1e-10



- PAM3 has the best performance for SNR margin
- IEEE always picked the lowest workable PAM
  - -A single symbol error leads to more bit errors for higher PAM levels
  - -DFE error propagation grows exponentially with PAM level
- Consistent with 802.3cg
  - -More resource of cg PHY can be reused

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3. Power supply

Consideration on SPoE for intrinsically safe operation

Single Pair Ethernet PoDL classification levels

	PoDL Classification															
	IEEE Std 802.3bu-2016										10Base-T1L IEEE Std 802.3cg-2019					
	12V unreg.		12V reg.		24V unreg.		24V reg.		48V reg.							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Vpse(max)[V]	18	18	18	18	36	36	36	36	60	60	30	30	30	58	58	58
Vpse(min)[V]	5.6	5.77	14.4	14.4	11.7	11.7	26	26	48	48	20	20	20	50	50	50
Ipi(max)[mA]	101	227	249	471	97	339	215	461	735	1360	92	240	632	231	600	1579
Pclass(min)[W]	0.566	1.31	3.59	6.79	1.14	3.97	5.59	12	35.3	65.3	1.85	4.8	12.63	11.54	30	79
Ppd(max)[W]	0.5	1	3	5	1	3	5	10	30	50	1.23	3.2	8.4	7.7	20	52
Vpd(min)[V]	4.94	4.41	12	10.6	10.3	8.86	23.3	21.7	40.8	36.7	14	14	14	35	35	35
Cable[AWG]											18	14	24	18	14	24
Cable Length[m]											1000	1000	300	1000	1000	300

Reference: https://www.aimvalley.com/wp-content/uploads/AimValley_Single-Pair-Ethernet_2021.pdf

Intrinsically safe parameters for 2-WISE power source ports and power load ports

	power source ports	power load ports
Maximum voltage	14V~17.5V	17.5V
Maximum current	380mA	380mA
Maximum power	5.32W	5.32W
Maximum internal capacitance	5nF	5nF
Maximum internal inductance	10uH	10uH

Reference: IEC TS 60079-47-2021

- For process industry, it is assumed that Trunk is located in Zone2 (Non-intrinsically safe), while Spur is located in Zone1/Zone0 (Intrinsically safe).
- According to IEC TS 60079-47-2021, for intrinsically safe 2-WISE system, the PSE/PD voltage, current and power are limited.
- With this, should we consider to add extra classes for single pair PoE used as spur links in intrinsically safe environments, for example: U_{PSE} of 15V, P_{pd} of 0.5W/1W/2W…

Summary

- 500m AWG18 / 200m AWG24 cable IL and RL have been measured
  -S4P file can be shared if needed; more measurement (IS cable, with connectors) is expected

- It is shown that defining Trunk IL limit based on 500m AWG18 is more reasonable, feasibility of which for 100M transmission is also presented

- Performance results are provided considering different PAM modulations, and PAM3 seems to be the best choice

- For Spur usage, it would be good for the group to define extra powering classes for 10BASE-T1L and 100BASE-T1L deployed in intrinsically safe environment

- An open question: shall we cover Spur bandwidth upgrading as well in the project?
  -as IL of AWG24 200m is similar with AWG18 500m

Thank you.

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