IEEE 802.3da – EMC noise margin

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Outline

- Follow-up discussion on consensus model definition
  - TX model:
    - https://www.ieee802.org/3/da/public/050422/beruto_3da_20220502_tx_model.pdf
  - RX model:
    - https://www.ieee802.org/3/da/public/0722/beruto_3da_20220711_rx_model.pdf
  - Integration of TX/RX with consensus model from Michael Paul
    - https://www.ieee802.org/3/da/public/0922/paul_02_da_09142022.pdf
  - Integration of TX/RX with channel model from Chris Di Minico
    - https://www.ieee802.org/3/da/public/0922/diminico_SPMD_01_09142022.pdf
    - https://www.ieee802.org/3/da/public/1122/diminico_SPMD_01_1122.pdf [1]
- Results shown in [1] indicate that there is little margin for EMC immunity on the presented link segment (75 mt, 30 nodes w/ and w/o compensation)
  - How to deal with this?

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Problem Statement

Starting point: simulations

- Data collected from https://www.ieee802.org/3/da/public/1122/diminico_SPMD_01_1122.pdf

Model	Max CWA at CORR > 0.65
75 m, 30 node, uncompensated, Min TX	100 mV_{p-p}
75 m, 30 node, uncompensated, Typical TX	150 mV_{p-p}
75 m, 30 node, compensated, Min TX	150 mV_{p-p}
75 m, 30 node, compensated, Typical TX	300 mV_{p-p}

CWA (V)	CORR_AVG	CORR_MAX	CORR_MIN	JITTER (ns)	JITTER_MAX (ns)
0	0.975174	1	0.8875	1.964992	6
0.05	0.973562	1	0.8625	2.03217	7
0.1	0.969372	1	0.825	2.241924	9
0.15	0.963706	1	0.775	2.545944	11
0.2	0.956932	1	0.75	2.935691	13
0.25	0.949302	1	0.7	3.388988	16
0.3	0.941119	1	0.65	3.902001	19
0.35	0.932468	1	0.55	4.465008	24
0.4	0.923128	1	0.4875	5.143244	39
0.45	0.913067	1	0.4625	6.092328	39

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10 Mb/s SPMD Enhancement TG

Noise environment

- Are these levels acceptable for industrial use cases?
- As shown in slide 8 of https://www.ieee802.org/3/da/public/0722/beruto_3da_20220711_noise_env.pdf
  - IEC61000-4-6 (Immunity to conducted disturbances, induced by radio-frequency fields) can be used as a baseline for defining the noise environment
  - Class 3 immunity level defines 10 V_{rms} of common-mode continuous wave (CW) noise coupled to the data lines
    - Calibrated, regardless of the coupling method (clamps or CDN)
    - Ranges from 150 kHz to (at least) 80 MHz with 1% step increment
    - Further modulated by 80% amplitude at 1 kHz
- How common-mode noise affects the PHY's immunity?
  1. The PHY shall tolerate the noise without clamping the voltage on the line
     - even when powered off!
  2. Part of the common mode voltage is converted to differential mode!

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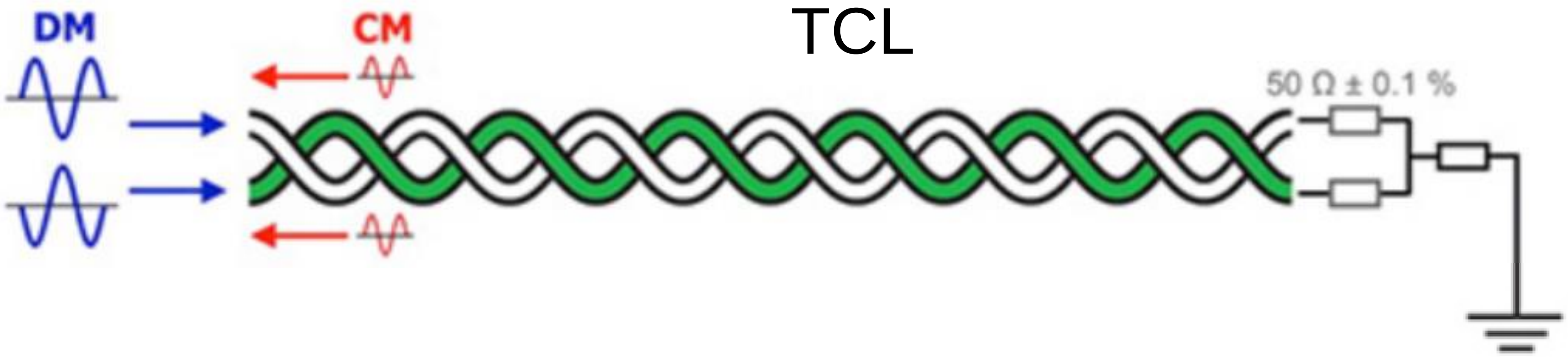
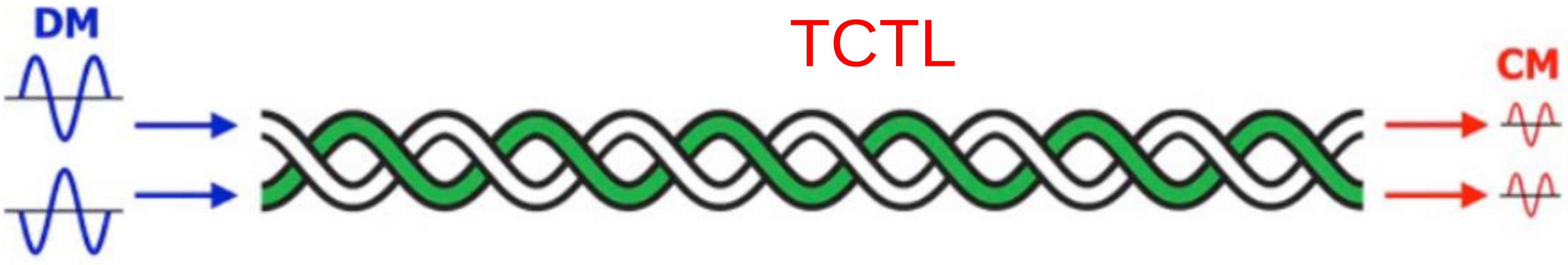
Problem statement - Mode Conversion Loss

Graphics from https://www.flukenetworks.com/

TCL



TCTL



- The conversion is symmetrical DM → CM (emission) or CM → DM (immunity)
- Just a change in sign!

MC limits

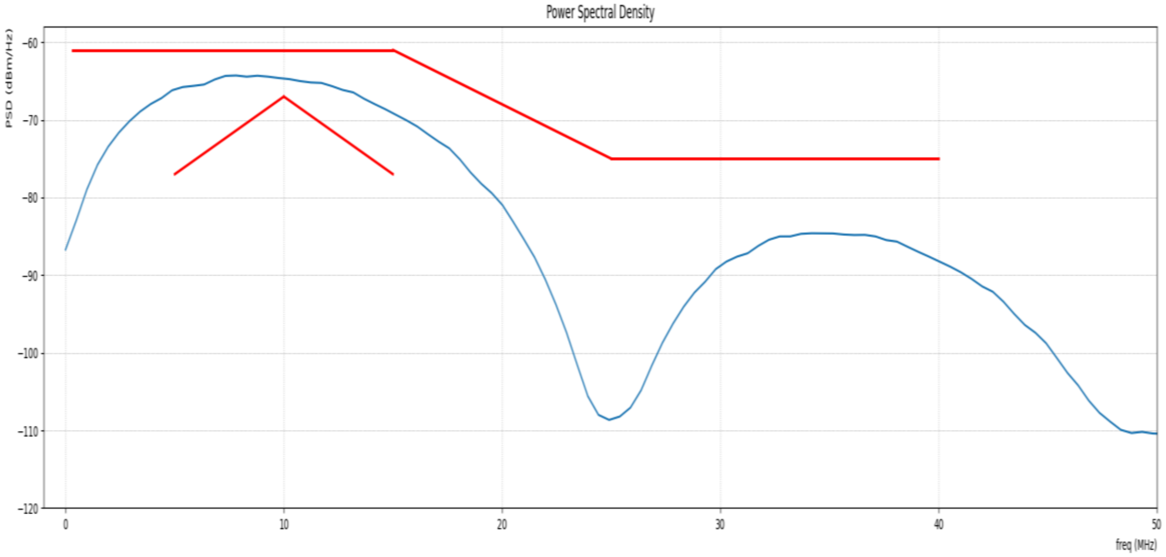
- 802.3cg Clause 147 adopted the MC definition from Clause 96
  - re-use of typical 100BASE-T1 cables (UTP) for automotive (~ AWG 26)
  - 43 dB in-band (1 MHz to 20 MHz)
- Doing the math:
  - 10 V_{rms} calibrated at the MDI + 80% modulation → 51 $V_{p\text{-}p}$ (max, CM)
  - Considering 43 dB of MC loss (TCTL) → 360 $mV_{p\text{-}p}$ (max, DM)
  - Taking some margin for tolerances/non-idealities → 400 $mV_{p\text{-}p}$ (max, DM)
- This exceeds even the **best-case** margin shown by simulations in https://www.ieee802.org/3/da/public/1122/diminico_SPMD_01_1122.pdf

Model	Max CWA at CORR > 0.65	
75 m, 30 node, uncompensated, Min TX	100 $mV_{p\text{-}p}$	-12 dB SNR !
75 m, 30 node, compensated, Typical TX	300 $mV_{p\text{-}p}$	-2.5 dB SNR !

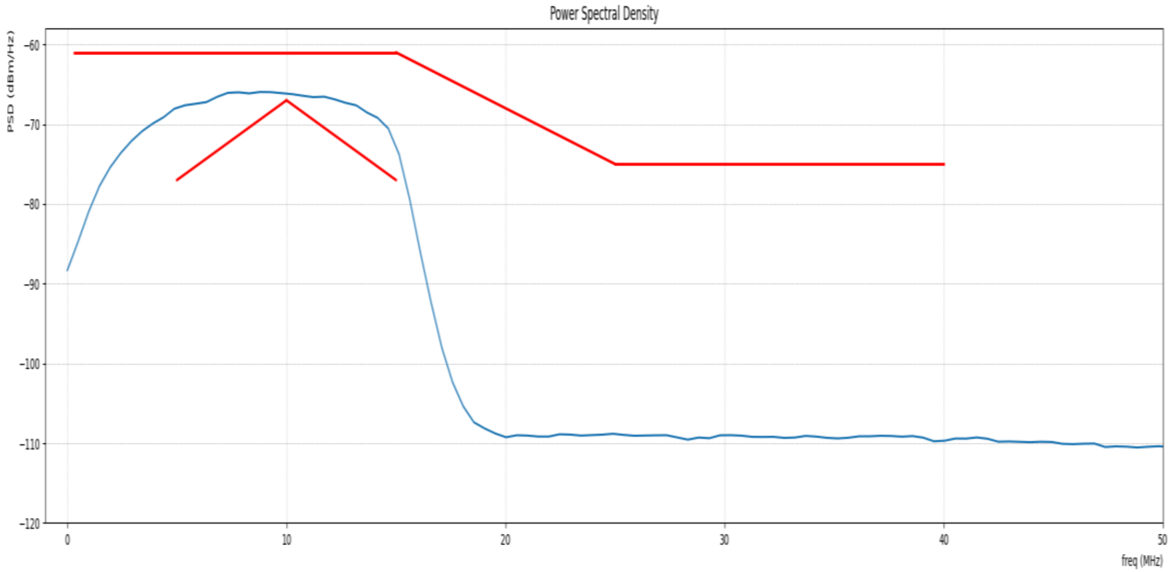
Potential Solutions

1. Further constrain the PSD

- There is a significant difference between the results obtained with the “typical PSD” transmitter model and the “Minimum compliant PSD” transmitter model
  - about 5 dB difference in SNR



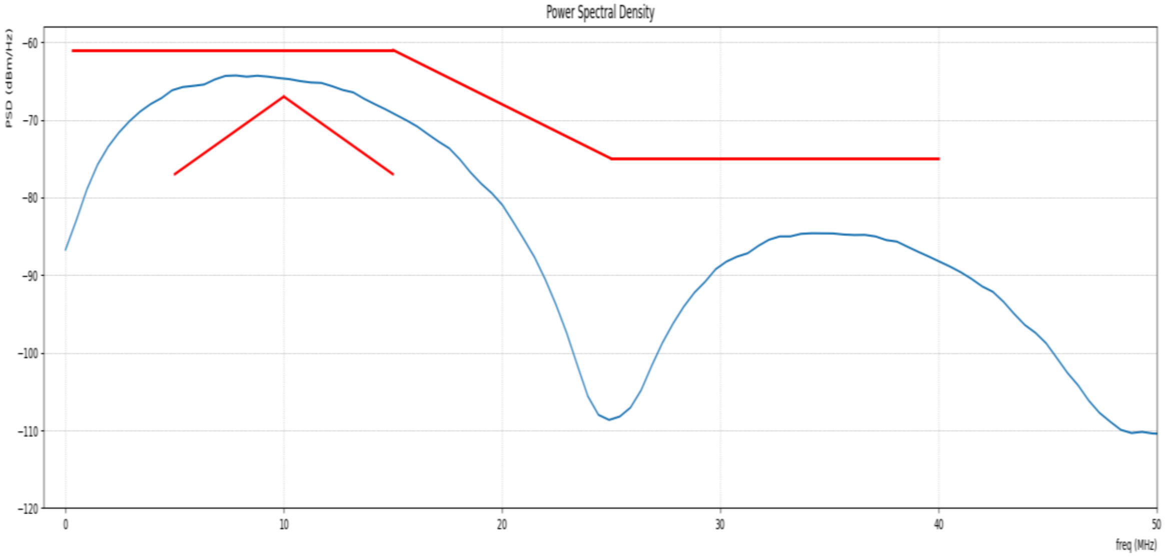
TYP

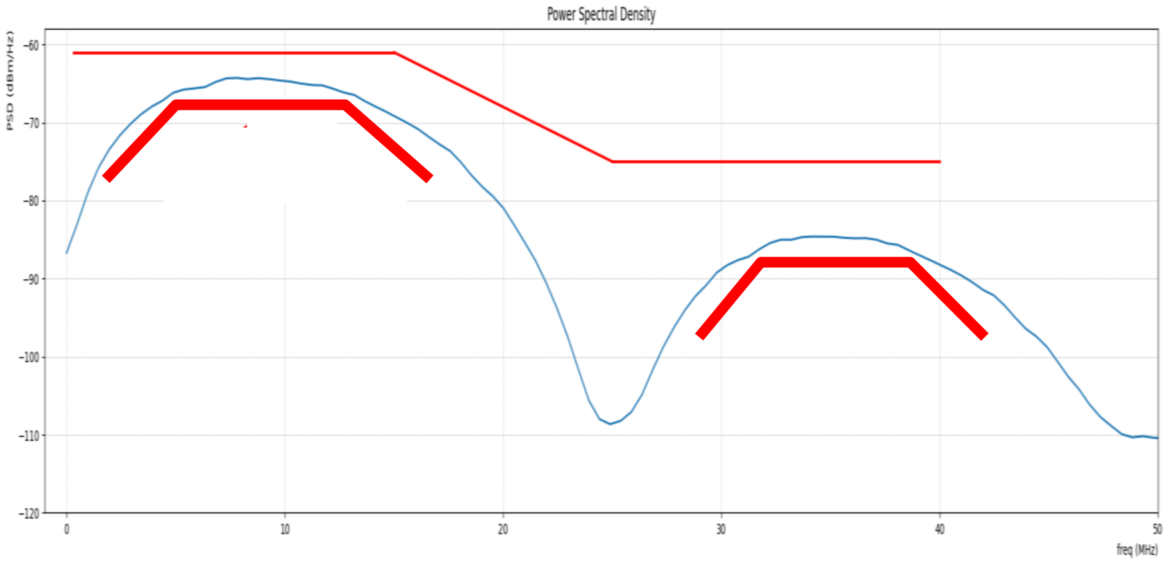


MIN

1. Further constrain the PSD

- There is a significant difference between the results obtained with the “typical PSD” transmitter model and the “Minimum compliant PSD” transmitter model
  - about 5 dB difference in SNR





OLD → NEW (?)

2. Increase the TX level

- Increasing the TX level to 2.4 $V_{p\text{-}p}$ yields ~ 7.6 dB of SNR

CWA	CORR_AVG	CORR_MAX	CORR_MIN	JITTER	JITTER_MAX
0.1	0.974432	1	0.8625	2.003142	7
0.2	0.971493	1	0.825	2.144271	8
0.3	0.967244	1	0.8	2.368208	9
0.4	0.96227	1	0.775	2.64529	11
0.5	0.956381	1	0.7375	2.99016	13

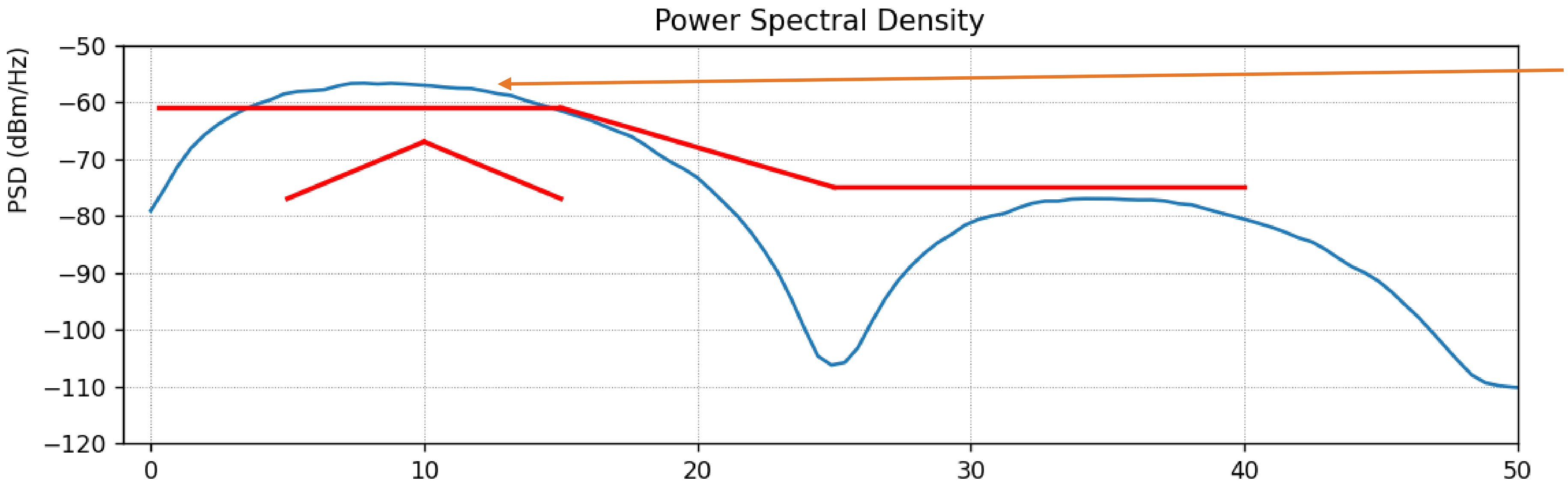
30 nodes, 75 m, compensated typ. TX

CWA	CORR_AVG	CORR_MAX	CORR_MIN	JITTER	JITTER_MAX
0.1	0.960001	1	0.775	2.029582	7
0.2	0.957892	1	0.7375	2.194503	8
0.3	0.95476	1	0.6875	2.451864	10
0.4	0.950683	1	0.6375	2.777494	11
0.5	0.945519	1	0.5375	3.162871	14

30 nodes, 75 m, uncompensated typ. TX

2. Increase the TX level

- Implications of increasing the TX level:
  - cross-talk to be re-evaluated, in principle
  - although, 10BASE-T1L has an option for 2.4 V already (not for intrinsic safety)
  - How to negotiate this option? There is no AN defined for multi-drop…
    - Could be a static setting / mandated for all 802.3da compliant PHYs
      - What about compatibility with 802.3cg?
      - May not be an issue as 802.3cg PHYs should tolerate a much higher differential signal, again because of EMC requirements



PSD limits shall be updated accordingly

2. Increase the TX level

- Other implications
  - A higher TX voltage would adversely affect EME (emissions)
  - However, 10BASE-T1S was mainly designed for meeting automotive requirements
  - Can we tolerate more emissions for building/industrial automation?
    - According to my experience → yes
- The relative cost of the PHY would increase
- The power consumption would increase significantly

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3. Define a better MC for the 10BASE-T1M channel

- Can we afford cabling / connectors with better MC than what is defined for 100BASE-T1?
- Ideally, we need to be at least 12 dB better (without changing the PSD)
  - But the final solution could be a mix of PSD / MC changes
- Use of shielded cables could be a solution, but expensive (and typically undesired because of installation complexity)
- QUESTION for cables/connectors manufacturers:
  - What can we reasonably mandate as minimum MC?

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Conclusions

Conclusions

- According to the simulations presented in https://www.ieee802.org/3/da/public/1122/diminico_SPMD_01_1122.pdf, we are missing at least 12 dB of SNR margin from the **worst-case** scenario (minimum compliant TX mode, no inline inductors compensation) to achieve IEC61000-4-6 class 3 conducted immunity requirements
- Changing the TX PSD is a potential solution
  - increases emissions and the PHY relative cost / power consumption
- Increasing the MC requirement for the harness is also a potential solution
  - Cables for industrial/building automation could be better than 100BASE-T1?
  - what's the trade/off between costs and performance?
  - What can reasonably be achieved?
- We need an additional requirement to prevent PHYs from clamping the voltage on the shared medium, affecting the ability of other nodes to communicate

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