IEEE P802.3cg
10BASE-T1S
Increased Transmit Voltage

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Purpose

- The purpose of this presentation is to:
  - Propose changes in IEEE P802.3cg Draft 2.1 for the addition of an increased transmit voltage option for 10BASE-T1S
  - Augment suggested remedy for comments #441 and #180

Original comment #441

- Comment
  - Market potential would benefit by 10BASE-T1S having an optional increased voltage level similar to 10BASE-T1L. Applications in elevators, lighting, and industrial automation have use for increased reach, higher node count, and improved immunity. Existing non-Ethernet systems with substantially similar modulation schemes have been successfully deployed within emissions limits.
- Proposed Change
  - Add an optional 2.4 Vpp differential transmit level as an auto-negotiated option for point-point and an engineered option for both point-point and multidrop.

Original comment #180

- Comment
  - Extended use-cases (e.g. in industrial with more nodes, longer reach, higher total capacitance/inductance), where immunitiy is more, while emmision is less of a factor may not be possible to cover with the current TX voltage of 1Vpp
- Proposed Change
  - Define the configurable, optional secondary TX Vpp of 2.4V (with appropriate tolerances) for T1S, and consider AutoNeg for auto-selection (similar to T1L) for Pt2Pt mode of operation

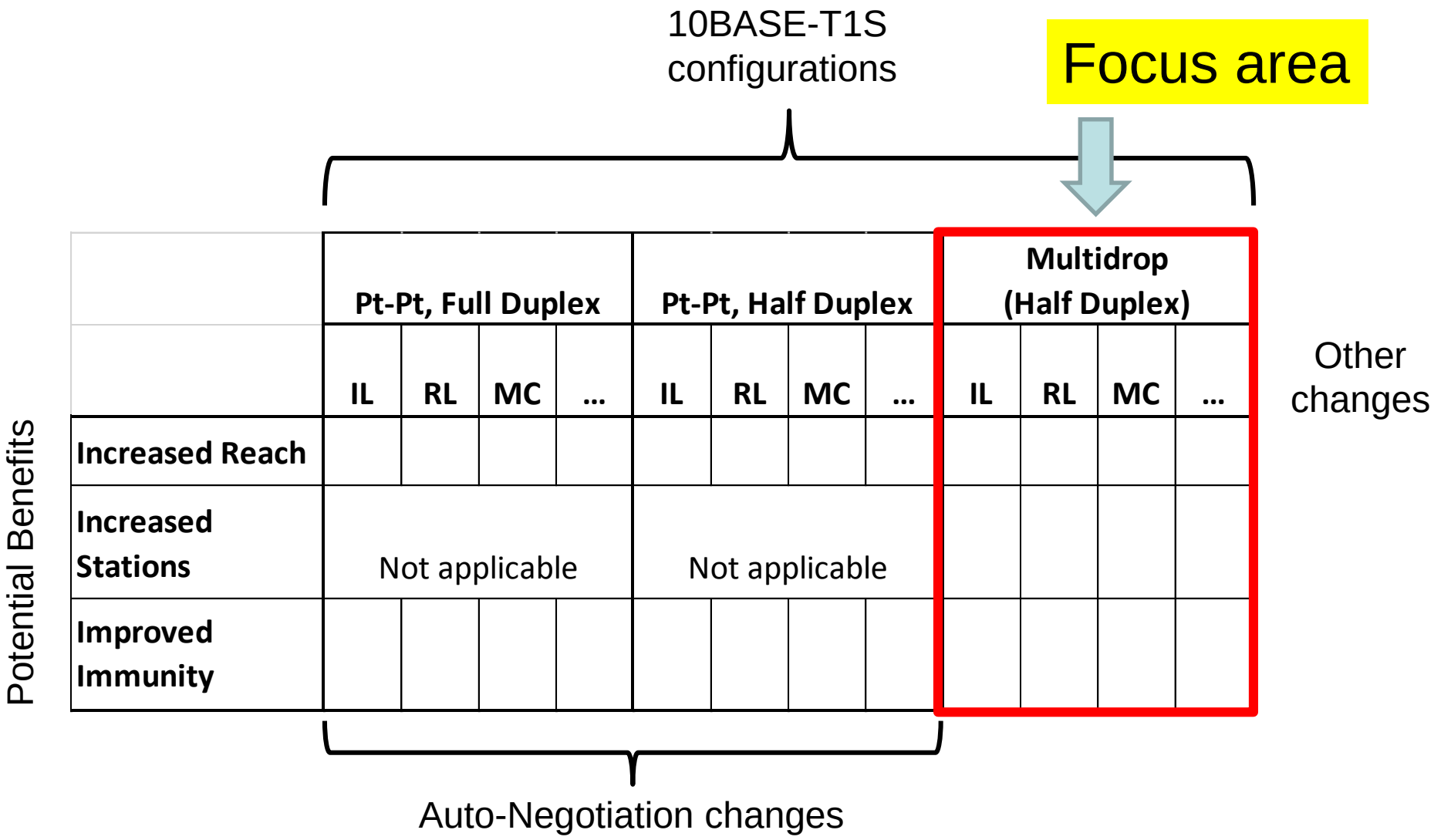
POTENTIAL MARKET

Examples

- In-cabinet Components, March 2017
  - http://www.ieee802.org/3/cg/public/Mar2017/brandt_cg_01_0317.pdf
  - 64M potential new Ethernet nodes
    - 15% attachment of 426M potential nodes
  - Enabler: 40 nodes on a 25 m multidrop
- Elevators, update of Sept. 2017
  - http://www.ieee802.org/3/cg/public/Nov2017/kattainen_huszak_3cg_01b_1117.pdf
  - 10M potential new Ethernet nodes
  - Enabler: 24 nodes on a 40 m multidrop
- Building Automation, slide 37
  - http://www.ieee802.org/3/cfi/0716_1/CFI_01_0716.pdf
  - Potential HVAC opportunity, some % of 200M

PROPOSAL

Potential changes



Multidrop proposal

- Add 2.4 Vpp transmit mode as an engineered option
- Only address increased reach and increased stations in the standard

Not all at once

	Multidrop (Half Duplex)			
	IL	**RL**	**MC**	**Ctot**
Increased Reach	+			
Increased Stations				+
Improved Immunity	Implementation-specific measures			

BRIEF TECHNICAL DISCUSSION

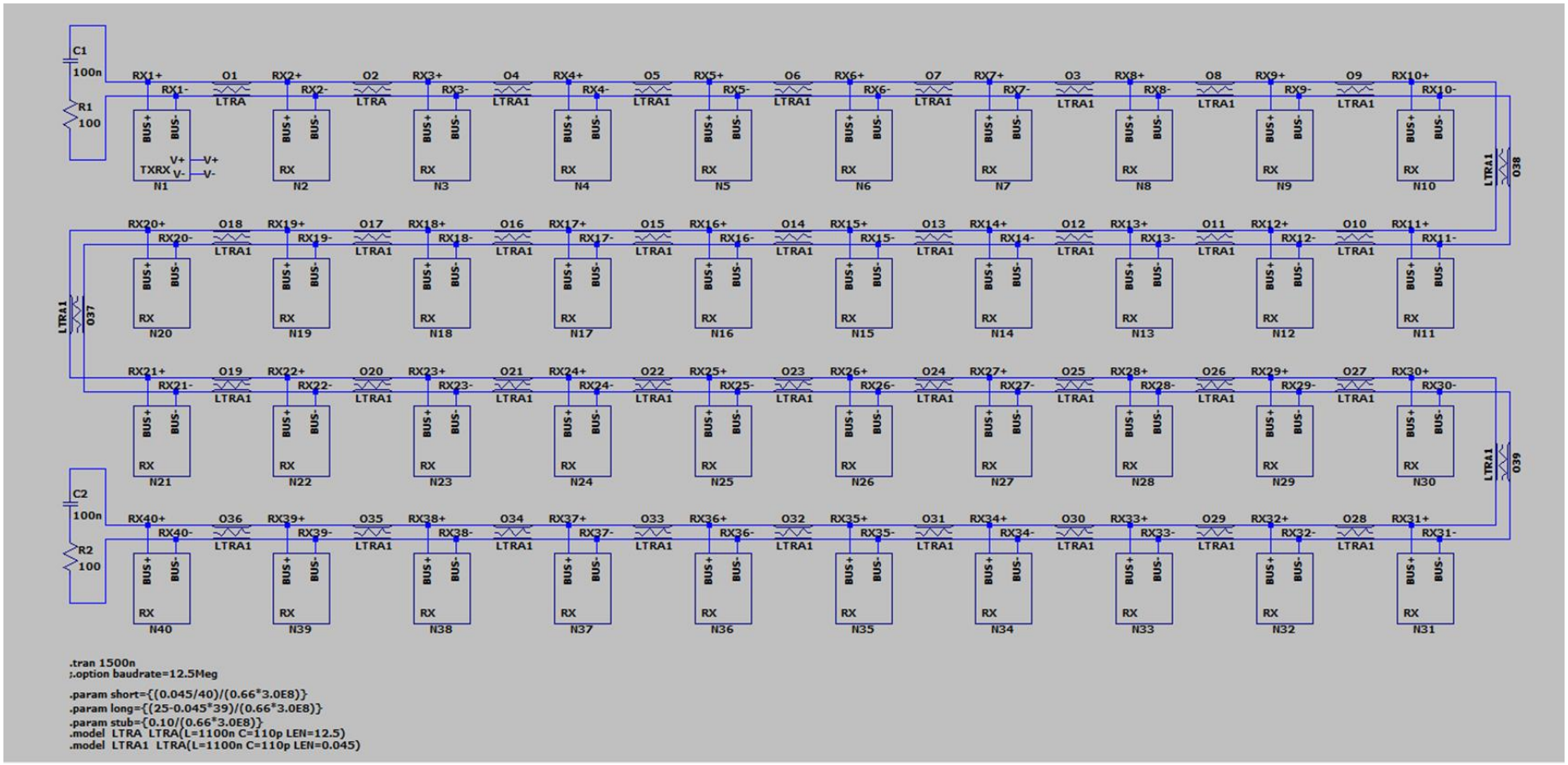
2.4 Vpp differential transmit signal

- 1.2 V differential achievable with 5 V power supply (Microchip)
- Reuse existing text and document structure from 10BASE-T1L and creates more consistency between the two PHYs

- 1.0 Vpp → 2.4 Vpp
- Voltage multiplier
  - 20 $\log_{10}(2.4)$ = 7.6 dB
- Power multiplier
  - 10 $\log_{10}(2.4^2)$ = 7.6 dB
- Relaxed emissions
  - May not be linear

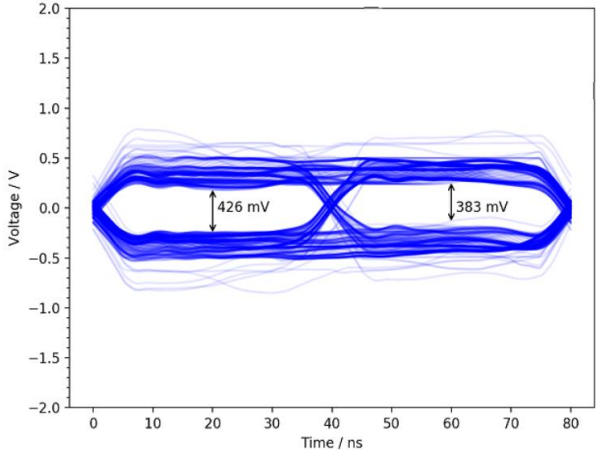
Simulation for Ctot

- 40 nodes @ 45 mm, far-end transmitter

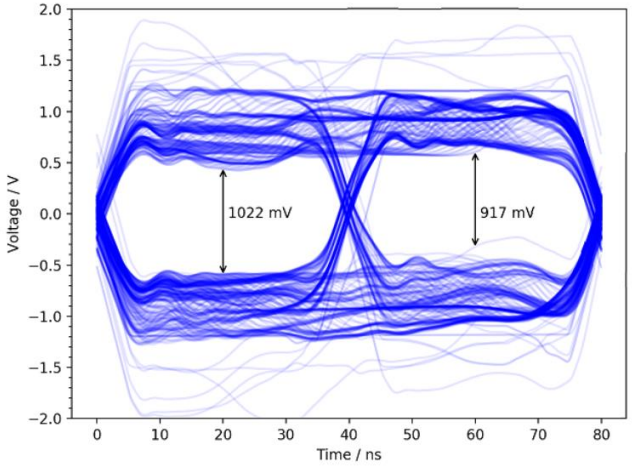


Composite Eye Openings
1 Vpp Versus 2.4 Vpp, various Ctot

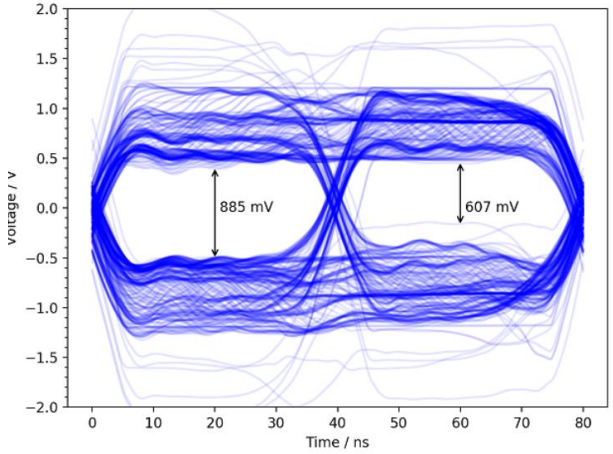
1V Vpp
40*4.5pf
180pf Ctot



2.4V Vpp
40*4.5pf
180pf Ctot



2.4V Vpp
40*9pf
360pf Ctot



Higher supply voltage is one enabling factor for higher node count

Emissions requirements

- There is a wide range of emissions requirements inside and outside of automotive

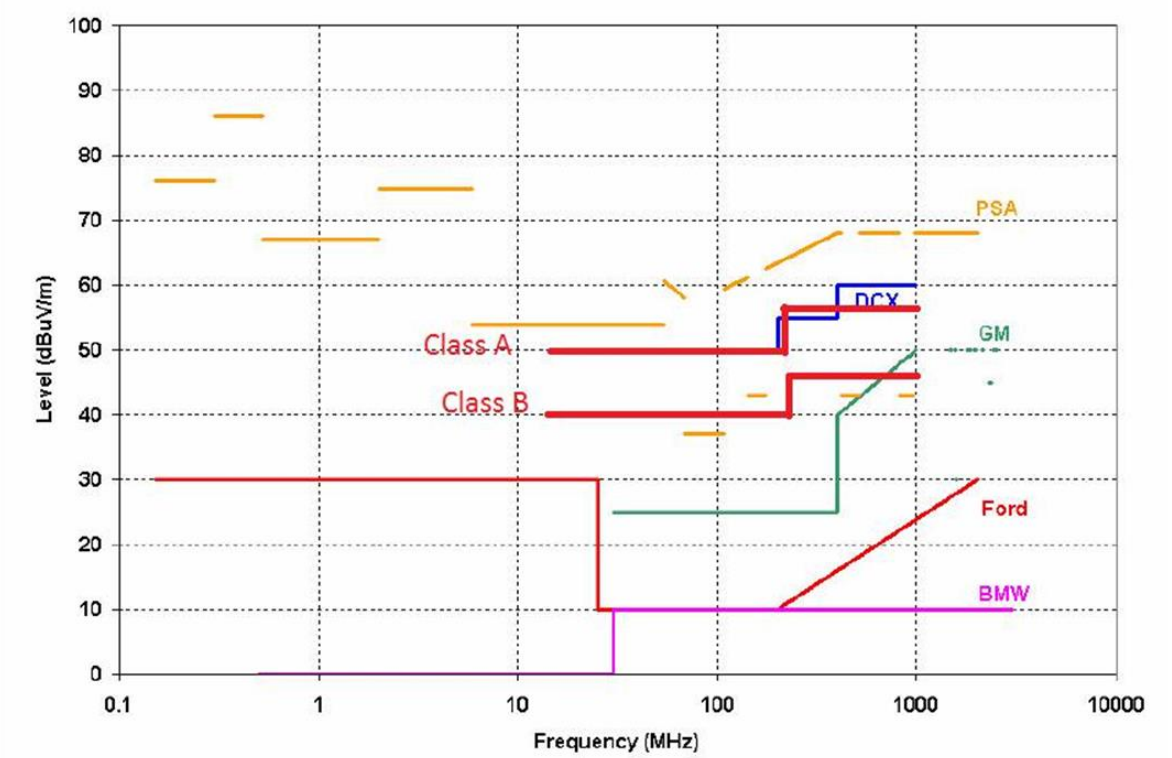
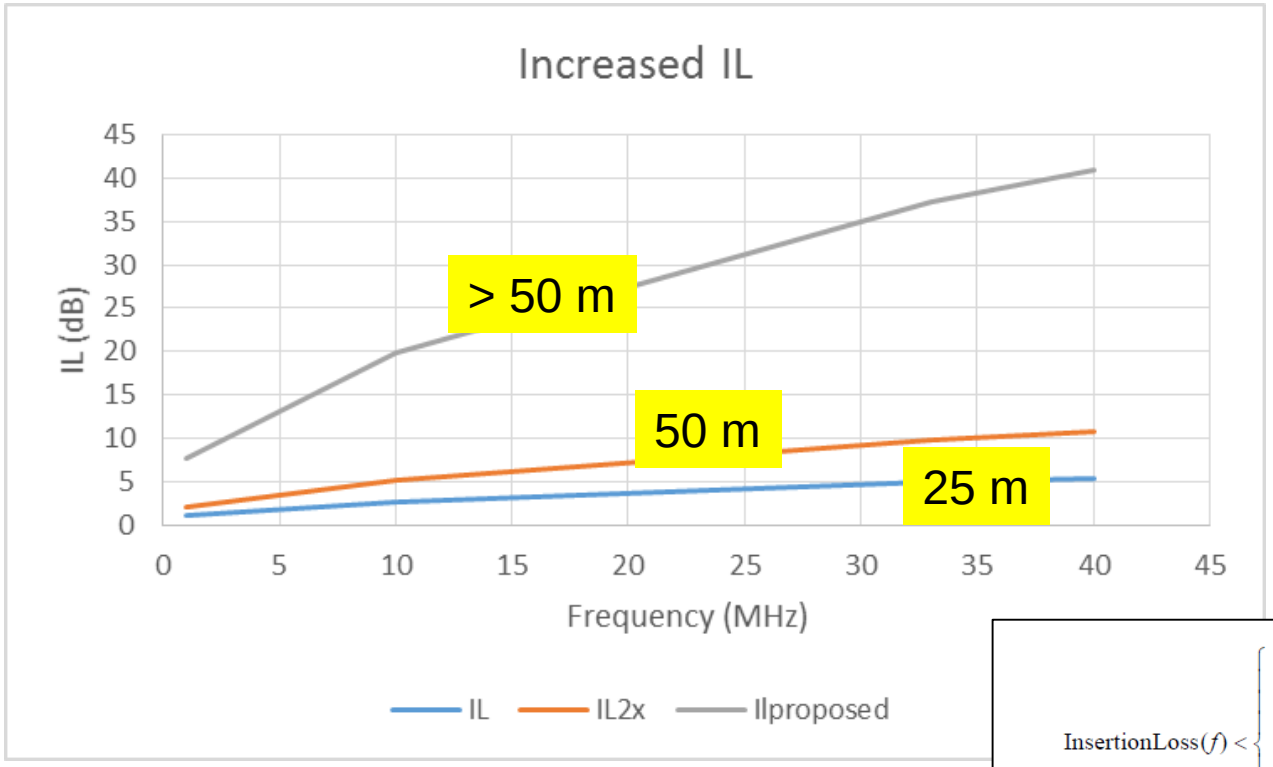


Figure 1: VM Radiated Emissions Limits

10's of dB

10BASE-T1S multidrop reach

- Increased reach should be achievable (7.6x?)



$$\text{InsertionLoss}(f) < \begin{cases} 1.0 + \frac{1.6(f-1)}{9} & 0.3 \le f < 10 \\ 2.6 + \frac{2.3(f-10)}{23} & 10 \le f < 33 \\ 4.9 + \frac{2.3(f-33)}{33} & 33 \le f \le 40 \end{cases} \text{ dB}$$

where

f is the frequency in MHz; $0.3 \le f \le 40$

TRANSMITTER

Optional 2.4 Vpp Transmitter Operating Mode

- Pg. 184, Line 54
- 147.5.4.1 Transmitter output voltage

- Change from:
  - The transmitter output voltage shall be 1 V ± 20% peak-to-peak differential.
- To:
  - The transmitter output voltage shall be 1.0 V ± 20% peak-to-peak differential (for the default1.0 Vpp operating mode) and 2.4 V ± 20% peak-to-peak differential (for the optional 2.4 Vpp operating mode). Transmitter output voltage can be set using the management interface or by hardware default set-up.

    The transmitter output voltage can be selected by setting bit 1.2299.12 (10BASE-T1S PMA control register) of the PHY Management register set as described in 45.2.1.186f.6. If MDIO is not implemented, a similar functionality shall be provided by another interface.

Transmitter Power Spectral Density (PSD)

- Pg. 185, Line 43
- 147.5.4.3 Transmitter Power Spectral Density (PSD)

- Change from:
  - The upper and lower limits are given in Equation (147–1) and Equation (147–2), and shown in Figure 147–15.
- To:
  - For the 1.0 Vpp differential transmit amplitude, the upper and lower PSD limits are given in Equation (147–1) and Equation (147–2), and shown in Figure 147–15.

    For the 2.4 Vpp differential transmit amplitude, the upper and lower PSD limits are given in Equation (147–1b) and Equation (147–2b), and shown in Figure 147–15b.

Upper PSD

- Pg. 185, Line 46
- 147.5.4.3.1 Upper PSD

- Change:
  - {Existing Clause Text}

- To:
  - Upper PSD limit for the 1.0 Vpp differential transmit amplitude:

    {Existing Clause Text}

    Upper PSD limit for the 2.4 Vpp differential transmit amplitude:

    {Existing Clause Text, modified as follows:
    Change Equation reference to 147-1b
    Change Equation limits:
    from -61 to -53.4
    from -40 to -32.4
    from -75 to -67.4
    }

Lower PSD

- Pg. 186, Line 1
- 147.5.4.3.2 Lower PSD

- Change:
  - {Existing Clause Text}

- To:
  - Lower PSD limit for the 1.0 Vpp differential transmit amplitude:

    {Existing Clause Text}

    Lower PSD limit for the 2.4 Vpp differential transmit amplitude:

    {Existing Clause Text, modified as follows:
    Change Equation reference to 147-2b
    Change Equation limits:
    from -87 to -79.4
    from -47 to -39.4
    }

PSD Mask

- Pg. 186, Line 10
- 147.5.4.3.3 PSD Mask

- Change:
  - {Existing Figure 147-15}

- To:
  - {Existing Figure 147-15, modified as follows:
    Change figure description to “Figure 147-15 - PSD upper and lower limits for 1.0 Vpp differential transmit amplitude”
    }

    {Existing Figure 147-15, modified as follows:
    Change figure description to “Figure 147-15b - PSD upper and lower limits for 2.4 Vpp differential transmit amplitude”
    Change limit lines to match 147-1b and 147-2b, and rescale figure
    }

RECEIVER

Receiver Electrical Specifications

- Pg. 187, Line 23

- Insert new clause:
  - 147.5.5 Receiver electrical specification

  The PMA shall meet the requirements specified in the PMA Receive function defined in 147.4.3 and the electrical specifications in this section. Unless otherwise specified, these requirements shall apply to receivers in both point-to-point and multidrop mode, if supported.
  - 147.5.5.1 Receiver differential input signals

  The receiver shall properly receive incoming data transmitted from a remote transmitter within the specifications defined in 147.5.4 after having passed through a link segment defined in 147.7 (point-to-point) or 147.8 (multidrop mode).
  - 147.5.5.2 Receiver 2.4 V differential input tolerance

  The receiver shall withstand without damage receive signals from transmitters using the 2.4 Vpp operating mode defined in 147.5.4.1.

LINK SEGMENT

Insertion Loss

- Pg. 187, Line 37
- 147.7.1 Insertion loss

- Change:
  - {Existing Clause text and Equation}

- To:
  - {Existing Clause text and Equation, modified as follows:
    Change text preceding existing equation 147-3 to the following: “For 1.0 Vpp differential transmit amplitude, the insertion loss of each 10BASE-T1S point-to-point link segment shall meet the values determined using Equation (147–3).
    }

    {Existing Clause text and Equation, modified as follows:
    Change Equation reference to 147-3b
    Change text preceding new equation 147-3b to the following: “For 2.4 Vpp differential transmit amplitude, the insertion loss of each 10BASE-T1S point-to-point link segment shall meet the values determined using Equation (147–3b).
    Change Equation limits:
    from “1.0 +” to “8.6 +”
    from “2.6 +” to “10.2 +”
    from “4.9 +” to “12.5 +”

    }

MIXING SEGMENT

MDI electrical specification

- Pg. 189, Line 29
- 147.9.2 MDI electrical specification

- Change:
  - “given in Table 147–3”

- To:
  - “given in Table 147-3 for 1.0 Vpp differential transmit amplitude, given in Table 147-3b for 2.4 Vpp differential transmit amplitude using Equation (147–3), and given in Table 147-3 for 2.4 Vpp differential transmit amplitude using Equation (147–3b).”

MDI electrical specification

- Pg. 190, Line 16
- 147.9.2 MDI electrical specification

- Change:
  - {Existing Table 147-3}

- To:
  - {Existing Table 147-3, modified as follows:
    Change table description to “Table 147-3 – Default MDI impedance limit parameters”
    }

    {Existing Table 147-3, modified as follows:
    Change table description to “Table 147-3b – Optional MDI impedance limit parameters”
    Change Ctot, Maximum value, from: 180 to: 360
    }

PMA REGISTERS

10BASE-T1S PMA control register

- Pg. 46, Line 11
- 45.2.1.186f 10BASE-T1S PMA control register (Register 1.2299)

- Change:
  - Table 45–150d

1.2299:13:12	Reserved	Value always 0	RO

- To:

1.2299.13	Reserved	Value always zero	RO
1.2299.12	Transmit voltage amplitude control	1 = Enable 2.4 Vpp operating mode 0 = Enable 1.0 Vpp operating mode	R/W

10BASE-T1S PMA control register

- Pg. 47, Line 28
- 45.2.1.186f 10BASE-T1S PMA control register (Register 1.2299)

- Insert heading and text, renumber and fix references:
  - 45.2.1.186f.6 Transmit voltage amplitude control (1.2299.12)

    Bit 1.2299.12 is used to set the 2.4 Vpp operating mode. If the PHY supports 2.4 Vpp operating mode, and the PHY is in multidrop mode, bit 1.2299.12 can be set to one, and the PHY shall operate in 2.4 Vpp operating mode according to 147.5.4.1. If bit 1.2299.12 is set to zero the PHY shall operate in 1.0 Vpp operating mode according to 147.5.4.1. The default value of bit 1.2299.12 is zero.

10BASE-T1S PMA status register

- Pg. 48, Line 12
- 45.2.1.186g 10BASE-T1S PMA status register (Register 1.2300)

- Change:
  - Table 45–150e

1.2300.12	Reserved	Value always 0	RO

- To:

1.2300.12	2.4 Vpp operating mode ability	1 = PHY has 2.4 Vpp operating mode ability 0 = PHY does not have 2.4 Vpp operating mode ability	RO

10BASE-T1S PMA status register

- Pg. 49, Line 11
- 45.2.1.186g 10BASE-T1S PMA status register (Register 1.2300)

- Insert heading and text:
  - 45.2.1.186g.6 2.4 Vpp operating mode ability (1.2300.12)

    When read as a one, this bit indicates that the 10BASE-T1S PHY supports a transmit level of 2.4 Vpp differential when in multidrop mode. When read as a zero, this bit indicates that the 10BASE-T1S PHY does not support a transmit level of 2.4 Vpp differential.

PICS

PICS: PMA/PMD management functions

- Pg. 65, Line 23
- 45.5 Protocol implementation conformance statement (PICS) proforma for Clause 45, Management Data Input/Output (MDIO) interface

- Insert PICs Items:

MM208	When bit 1.2299.12 is set to one, the 10BASE-T1S PMA transmits using the 2.4 Vpp operating mode	45.2.1.186f.6		PMA:M	Yes [ ] N/A [ ]
MM209	When bit 1.2299.12 is set to zero, the 10BASE-T1S PMA transmits using the 1.0 Vpp operating mode	45.2.1.186f.6		PMA:M	Yes [ ] N/A [ ]

PICS: Major capabilities/options

- Pg. 194, Line 13
- 147.12.3 Major capabilities/options

- Insert Item:

*RTDL	2.4 Vpp operating mode	147.5.4.1		O	Yes [ ] No [ ]

PICS: PMA electrical specification

- Pg. 198, Line 9
- 147.12.4.6.2 PMA electrical specification

- Change:

PMAE12	Transmitter output voltage	147.5.4.1.1	1.0 V ± 20 % peak-to-peak differential when measured on test mode 1	M	Yes [ ]

- To:

PMAE12	Transmitter output voltage	147.5.4.1.1	2.4 V ± 20% peak-to-peak differential in the 2.4 Vpp operating mode when measured on test mode 1, 1.0 V ± 20% peak-to-peak differential in the 1.0 Vpp operating mode when measured on test mode 1	RTDL: M	Yes [ ] N/A [ ]

PICS: PMA electrical specification

- Pg. 198, Line 18
- 147.12.4.6.2 PMA electrical specification

- Change:

PMAE15	Transmit power spectral density	147.5.4.3	Between the upper and lower masks specified in Equation (147–1) and Equation (147–2) when measured on test mode 3	M	Yes [ ]

- To:

PMAE15	Transmit power spectral density	147.5.4.3	Between the upper and lower masks specified in Equation (147–1) and Equation (147–2) in the 1.0 Vpp operating mode when measured on test mode 3 Between the upper and lower masks specified in Equation (147–1b) and Equation (147–2b) in the 2.4 Vpp operating mode when measured on test mode 3	RTDL: M	Yes [ ] N/A [ ]

PICS: PMA electrical specification

- Pg. 198, Line 39
- 147.12.4.6.2 PMA electrical specification

- Insert:

PMAE20	Transmitter output voltage setting	147.5.4.1	Default setting chosen by Auto-Negotiation, by setting bit 1.2299.12 as described in 45.2.1.186f.6 when MDIO implemented, similar functionality provided otherwise	RTDL:O	Yes [ ] No [ ] N/A [ ]

PICS: Point-to-point link Segment characteristics

- Pg. 199, Line 6
- 147.12.4.7 Point-to-point link Segment characteristics

- Change:

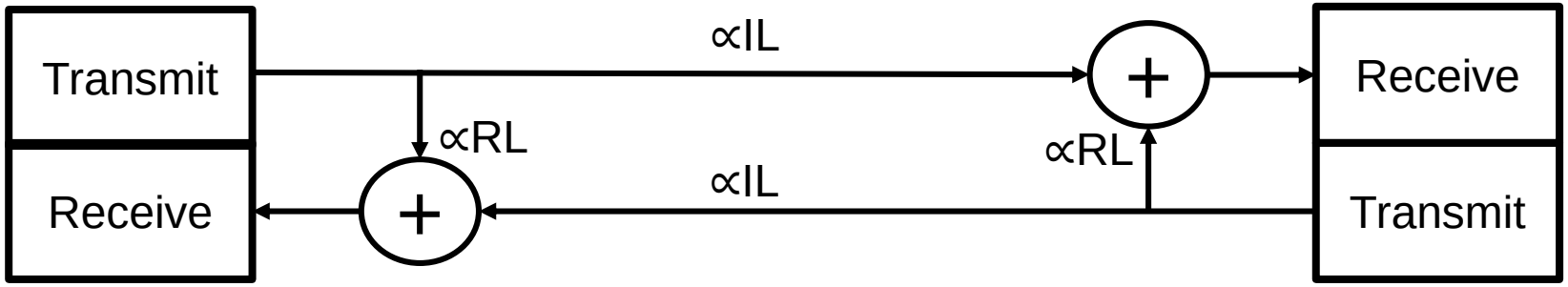
PPLS1	Insertion loss	147.7.1	See Equation (147–3)	M	Yes [ ]

- To:

PPLS1	Insertion loss	147.7.1	Equation (147-3) in the 1.0 Vpp operating mode Equation (147-3b) in the 2.4 Vpp operating mode	RTDL: M	Yes [ ] N/A [ ]

PT-PT ANALYSIS AND PROPOSAL

Full-duplex situation



- An attenuated transmit signal is received, based on IL
- Receiver subtracts its own transmission (if any), but transmit reflections remain and are added to the receive signal
- Echo cancellation can compensate reflections
  - 10BASE-T1S has no defined echo cancellation method, but it is not precluded
- Receive threshold [compensated] must exceed reflection limit

- For 1 Vpp differential transmit signal:

$$\text{ReturnLoss}(f) > \begin{cases} 14 & 0.3 \le f < 10 \\ 14 - 10\log_{10}\left(\frac{f}{10}\right) & 10 \le f \le 40 \end{cases} \text{ dB}$$

⟹ 200 mVpp

⟹ 200 to 400 mVpp

Full-duplex 2.4 Vpp implications

	Existing RL				RL increased by 7.6 dB			
Increased RX threshold	No	Yes	No	Yes	No	Yes	No	Yes
Echo cancellation	No	No	Yes	Yes	No	No	Yes	Yes
Increased Reach		No	Yes	No	Yes	No	Yes	No
Improved Immunity		Yes	Partial	Yes	No	Yes	Partial	Yes

- Without some measure, full-duplex communication may fail (echo may increase 2.4x)
- RL may be increased by 7.6 dB
  - Difficult specification to achieve
- Implementation-specific measures include a combination of:
  - Increased RX threshold
    - Cancels any reach gain from increased IL
    - Improves immunity *between* transmissions
  - Echo cancellation
    - Not standardized
    - Improves immunity *during* transmissions

Auto-Negotiation

- 2.4 Vpp Transmit mode is used in more demanding situations
- 10BASE-T1S uses DME, so does the LSM AN
  - 1 Vpp AN may not work in the demanding situations
  - 2.4 Vpp AN could be used
    - PHYs with only 1 Vpp must at least tolerate the higher voltage AN

Pt-pt proposal

- Rather than complicate 10BASE-T1S and increase link segment requirements - utilize 10BASE-T1L in demanding situations
  - Increased reach
  - Echo cancellation maintains reasonable RL
  - LSM AN uses lower complexity modulation than data transfer
  - Unshielded and shielded options