TCI RL & IL Proposal

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Contributors – Thanks!

Based on work by:

- Michael Paul, ADI
- Stephan Schreiner, Rosenberger
- Tim Baggett, Microchip
- Howard Hicks, Microchip

Issues

The new comment seeks to resolve the author's unsatisfied comment i-38 on D3.0, and the issue goes comment 115 on D2.2 in working group ballot (Stephan Schreiner)

- Changes to the TCI return loss specification, with loading for power, were overly restrictive on measurements
- Changes to the TCI return loss specifications with loading for power, were inconsistent with the requirements for TCI insertion loss.

This contribution does not resolve a related issue – the Mixing Segment return loss is inconsistent with a loaded mixing segment

- Suggest that this be handled separately – that mixing segment return loss be specified only for unloaded mixing segments (i.e., without Cl 189 loaded nodes attached)

Clause 189 TCI Return Loss

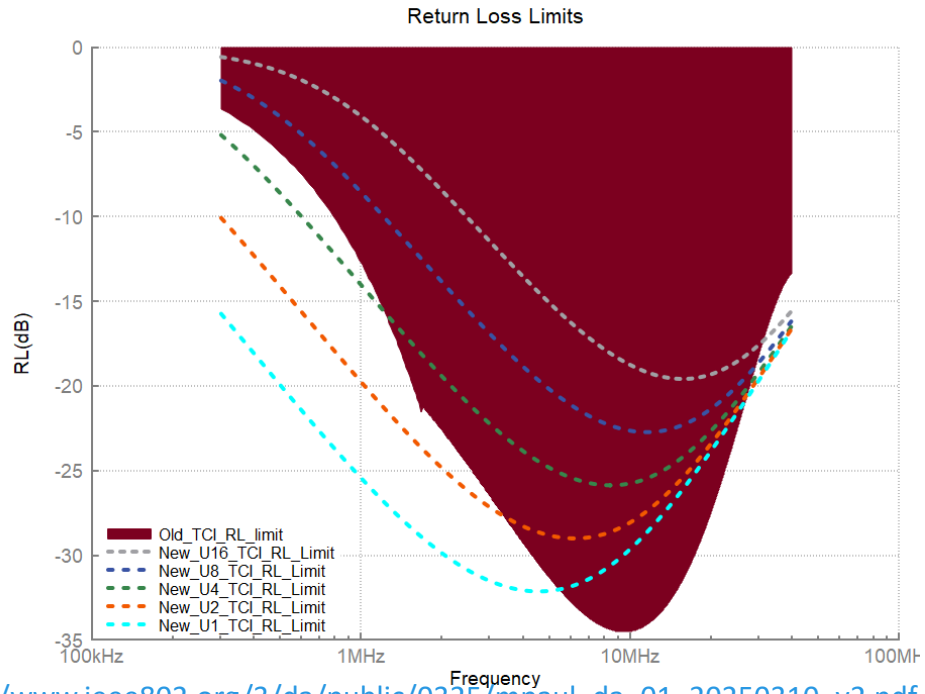
$$\mathrm{RL}(f) \geq \left\{ -10\log_{10}\left(\frac{10000 + \frac{(40.194f)^2}{N_{UNIT}}}{10000 + \left(\frac{2010f}{N_{UNIT}}\right)^2} + \frac{f^{2.5}}{480000} \right) \quad 0.3 \leq f \leq 40 \right\} \mathrm{dB} \qquad (189\text{–}1)$$

Provides RL dependent on unit loading for clause 189 MPIs that are also TCIs

Proposed in https://www.ieee802.org/3/da/public/0325/mpaul_da_01_20250310_v2.pdf

Has fairly little margin to small inductor implementations in the critical 7 to 12 MHz region

Based largely on lumped element components (e.g., inductors) used for “in-and-out” topologies



From: https://www.ieee802.org/3/da/public/0325/mpaul_da_01_20250310_v2.pdf

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Schreiner August 2025 proposal

Based on initial measurements of “in-line + drop” ferrite TCI implementations to clause 189 specification

Validated by modeling ISI as noise to enable topology-insensitive limits (see zimmerman_3da_01a_052024.pdf for methodology)

Further validated by consensus-model simulations of stress cases (thank you, Howard!)

$$RL(f) = -10 * log10\left(\frac{10e3 + \frac{(40.192f)^2}{N_{UNIT}}}{10e3 + \left(\frac{2010f}{N_{UNIT}}\right)^2} + \frac{f^{\cancel{2.5}\ 3.5}}{\cancel{480e3}\ 9500e3}\right) \text{ dB}$$

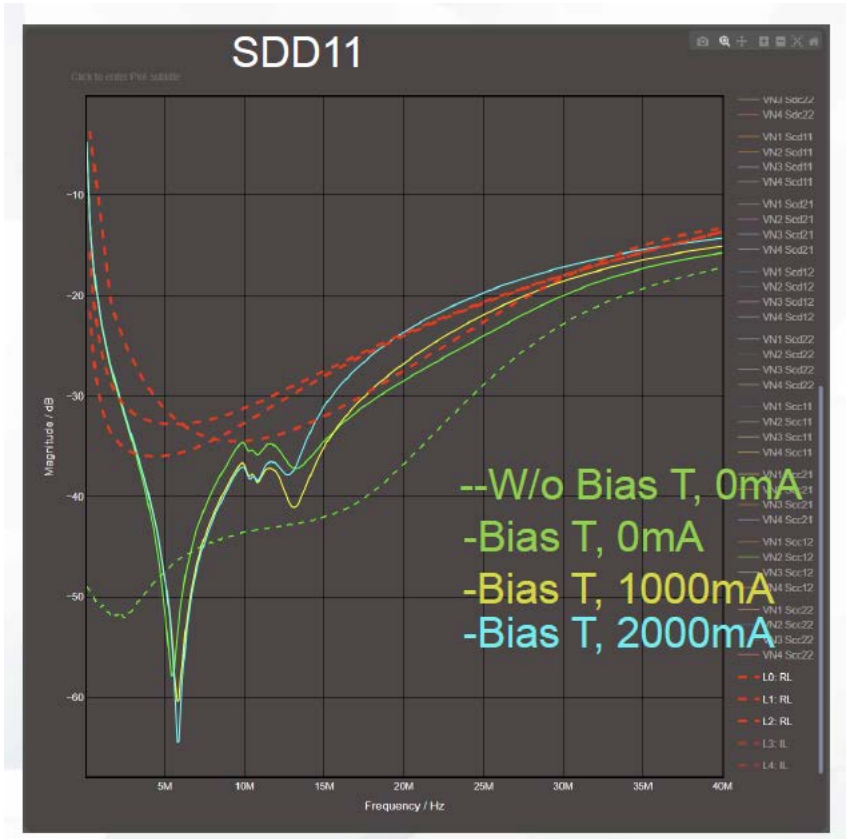
Schreiner Sept 2025 Proposal

https://www.ieee802.org/3/da/public/0925/schreiner_3da_01__september_2025.pdf compares to measured results with ferrite “inline + drop” TCI implementations to Clause 189 specification

- Requires higher slope on return loss at frequencies > 10 MHz
- Also points out insertion loss of TCI needs to be adjusted

$$RL(f) = -10 * log10\left(\frac{10e3 + \frac{(40.192f)^2}{N_{UNIT}}}{10e3 + \left(\frac{2010f}{N_{UNIT}}\right)^2} + \frac{f^{\cancel{2.5}\ 5}}{\cancel{480e3}\ 650e6}\right) \text{ dB}$$

Proposed equation validates to provide slightly better performance than existing equation 189-1, due to more stringent RL in the critical 5-12 MHz region



From: https://www.ieee802.org/3/da/public/0925/schreiner_3da_01__september_2025.pdf

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Problem: Inconsistency

Paul “in-and-out” models for small inductors & component variation don’t work with Schreiner “in-line + drop” models, AND

Schreiner models don’t work with Paul’s more stringent return loss at higher frequencies

Neither model alone fits both implementation styles

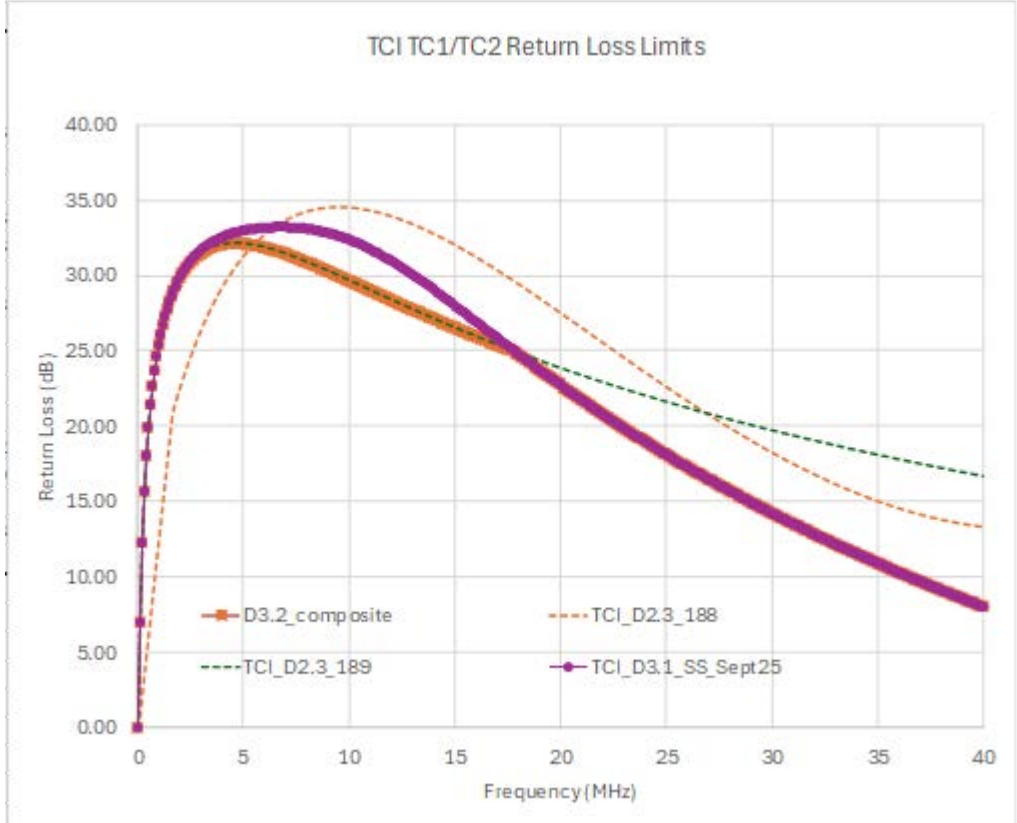
Solution: Split the frequency ranges

Schreiner proposed RL from Sept 2025 allowed decreased return loss above 18 MHz

- This does not impact performance
- Crossover frequency is fairly independent of unit loading
- Equation 189-1 is worse (allows more RL) below 18 MHz, but has been shown to be tolerable

Proposal:

- Form “Composite” RL from existing 189-1 return loss below 18 MHz, and Schreiner RL above 18 MHz



Clause 188, Clause 189, and proposed Schreiner (SS_Sept25) and composite RL specifications for 1 UL

Change to Equation 189-1

Change upper frequency of existing equation to 18 MHz

$$RL(f) \geq \begin{cases} -10\log_{10}\left(\dfrac{10000 + \dfrac{(40.194f)^2}{N_{UNIT}}}{10000 + \left(\dfrac{2010f}{N_{UNIT}}\right)^2} + \dfrac{f^{2.5}}{480000}\right) & 0.3 \leq f \leq \overset{18}{\cancel{40}} \end{cases} \text{dB} \qquad (189\text{–}1)$$

Add additional range to the equation for n18 MHz to 40 MHz:

$$RL(f) \geq -10 * log10\left(\frac{10e3 + \dfrac{(40.192f)^2}{N_{UNIT}}}{10e3 + \left(\dfrac{2010f}{N_{UNIT}}\right)^2} + \frac{f^{\overset{5}{\cancel{2.5}}}}{\cancel{480e3}\ 650e6}\right) \text{dB}$$

$18 < f \leq 40$

Performance

Composite gives equivalent performance to Equation 189-1

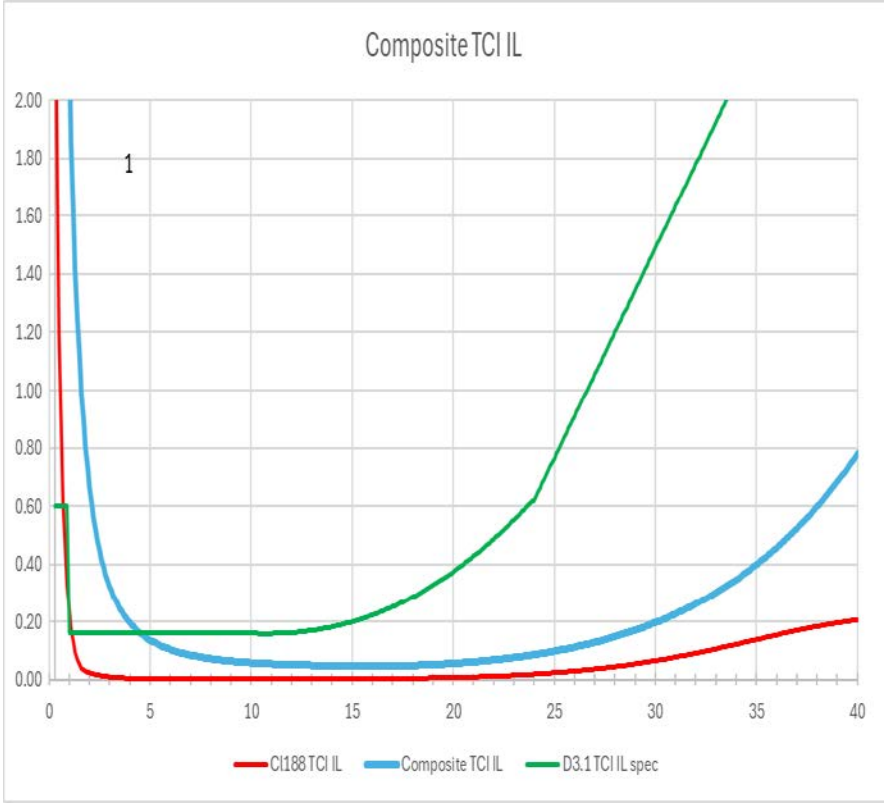
						Losses rel to D2.3_189	
Nload	TCI_D2.3_188	TCI_D2.3_189	TCI_D3.1_SS_Sept25	D3.2_composite		TCI_D3.1_SS_Sept25	D3.2_composite
1	18.10	14.57	15.60	14.57		-1.03	0.00
2	18.10	15.22	15.83	15.22		-0.61	0.00
3	18.10	15.40	15.84	15.40		-0.44	0.00
4	18.10	15.45	15.79	15.44		-0.34	0.00
5	18.10	15.43	15.72	15.43		-0.29	0.00
6	18.10	15.40	15.64	15.40		-0.25	0.00
7	18.10	15.34	15.56	15.34		-0.22	0.00
8	18.10	15.28	15.48	15.28		-0.20	0.00
9	18.10	15.21	15.39	15.21		-0.18	0.00
10	18.10	15.14	15.31	15.14		-0.16	0.00
11	18.10	15.07	15.22	15.07		-0.15	0.00
12	18.10	15.00	15.14	15.00		-0.14	0.00
13	18.10	14.93	15.06	14.93		-0.13	0.00
14	18.10	14.86	14.98	14.86		-0.13	0.00
15	18.10	14.79	14.91	14.79		-0.12	0.00
16	18.10	14.72	14.83	14.72		-0.11	0.00

TCI Insertion Loss

As Schreiner points out, the TCI IL is inconsistent with the RL

- Reflected energy doesn't go through the TCI…
- The issue here is at low frequencies
- It also doesn't matter for performance…

Frankly, we didn't need to specify insertion loss all the way to 0.3 MHz for a DME system, but we are stuck with it from 802.3cg



Change for TCI Insertion Loss

188.9.1.1 TCI insertion loss: change low frequency range of Equation 188-6) from 0.6 dB to be: $3 - (f\text{-}0.3)*2.84$ dB $0.3 < f < 1.3$

Add the following text after Equation 188-6:

When the TCI incorporates a Clause 189 MPI see 189.6.1

189.6.1:

- Change title to:
  MPI electrical specifications for MPIs that are also Clause 188 TCIs
- Add new text at the end of 189.6.1:

When the MPI is also a TCI, the TCI insertion loss from TC1 to TC2 shall meet the values of equation 189-2 at frequencies below 5 MHz. At frequencies above 5 MHz, the TCI insertion loss specified by equation 188-6 shall apply.

$$IL(f) <= 0.16 - 10*\log\_10(1 - 10^{(-RL(f)/10)}) \quad 0.3 < f < 5 \text{ MHz} \quad (189\text{-}2)$$

where RL(f) is the return loss limit specified by Equation 189-1 for the number of unit loads of the MPI

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The last missing piece: Mixing Segment RL

The mixing segment RL is a complicated function of both the loading and the matching of the cabling in the mixing segment.

It is desirable to separate the matching of the cabling from loading of a powered mixing segment

Comment i-39 attempted to address the fact that the mixing segment return loss is unlikely to be met with loaded clause 189 (powered) loads attached. The remedy was that matching of the cabling was sufficient and that could be determined with clause 188 loading. A clarification is needed here if the offered solution in i-39 can't find consensus.

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Summary

Suggest:

- Adopt change to clause 189 TCI Return Loss on Slide 9
- Adopt changes to clause 188 and 189 TCI Insertion Loss on slide 12
- Consider reopening comment i-39 for Mixing Segment Return Loss