Experimental Results of PoDL Coupling Network for 1000BASE-T1

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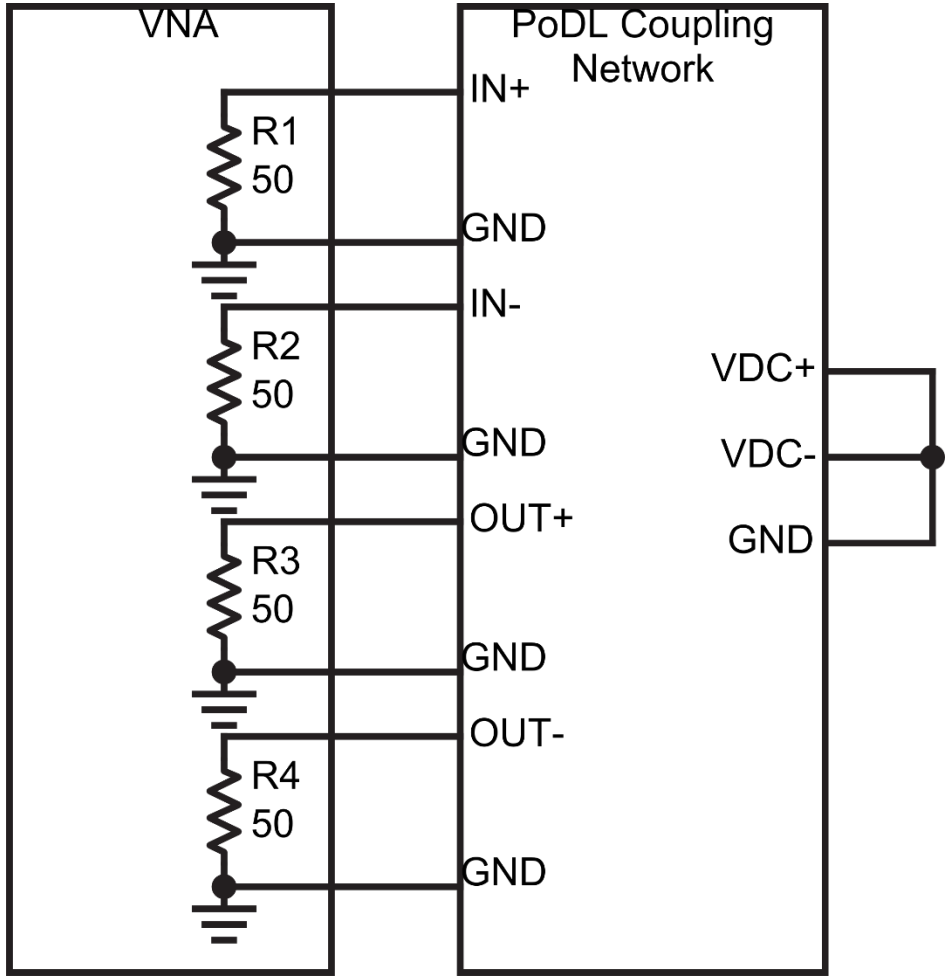
Requirements for PoDL Coupling Network

- Meet PHY requirements at MDI
  - Return loss
  - Mode conversion loss
- PoDL primary application will be for use with 1000BASE-T1.
  - Existing 1000BASE-T1 return loss limits are potentially unfeasible with real implementations of the PoDL coupling network.
- Meet power requirements at PI
  - Total DCR < 2 ohms
  - Saturation current greater than 400mA.
- Achieve a low enough solution cost and small enough footprint in order to be economically feasible.

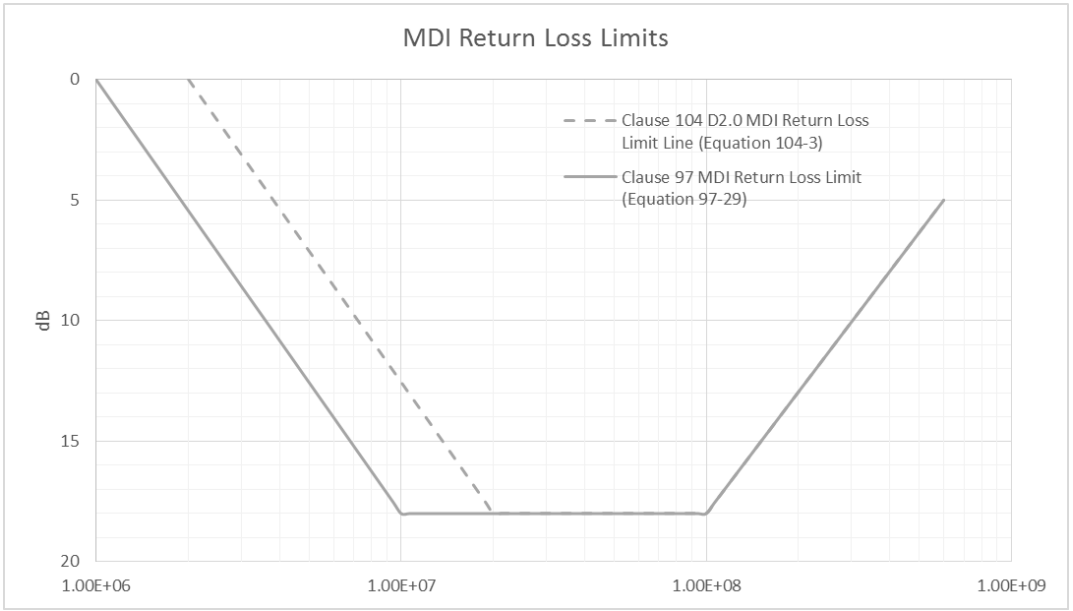
PoDL Coupling Network Setup and Measurement

- The initial approach assumed a classic 4-port configuration for characterization with a VNA using 50 ohm terminations, SMA connectors, and coaxial cables.
- The setup shown here was used to measure the performance of the PoDL coupling network prototype circuit.
- Subsequent testing will use UTP connectors and cables.



MDI Return Loss Limits

- MDI return loss equation 97-29 was relaxed below 20MHz in order to create MDI return loss equation 104-3 in PoDL Clause 104 D2.0.
  - Having a separate return loss specification in Clause 104 for 1000BASE-T1 creates the potential for confusion.
- Propose that equation 104-3 be adopted as the new equation 97-29.



$$(97-29)MDI\ RL\ (dB) \geq \begin{cases} 18 - 18 \times log_{10}\left(\frac{10}{f}\right) & 1 \leq f < 10 \\ 18 & 10 \leq f < 100 \\ 18 - 16.7 \times log_{10}\left(\frac{f}{100}\right) & 100 \leq f < 600 \end{cases}$$

$$(104-3)MDI\ RL\ (dB) \geq \begin{cases} 18 - 18 \times log_{10}\left(\frac{20}{f}\right) & 2 \leq f < 20 \\ 18 & 20 \leq f < 100 \\ 18 - 16.7 \times log_{10}\left(\frac{f}{100}\right) & 100 \leq f < 600 \end{cases}$$

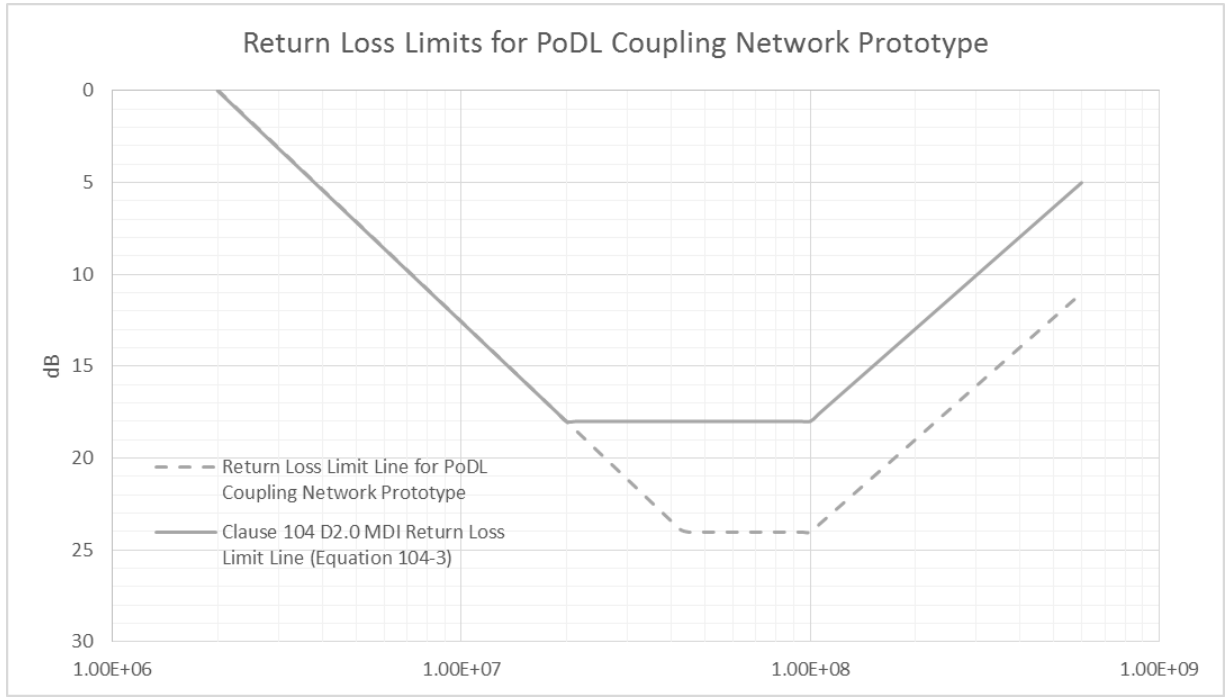
where f is frequency in MHz

Return Loss Limit for PoDL Coupling Network Prototype

- The PoDL coupling network must demonstrate margin to equation 104-3 in order for the MDI/PI to be feasible.
- The following limit line was used in order to provide 6dB of margin for the PHY's input capacitance.

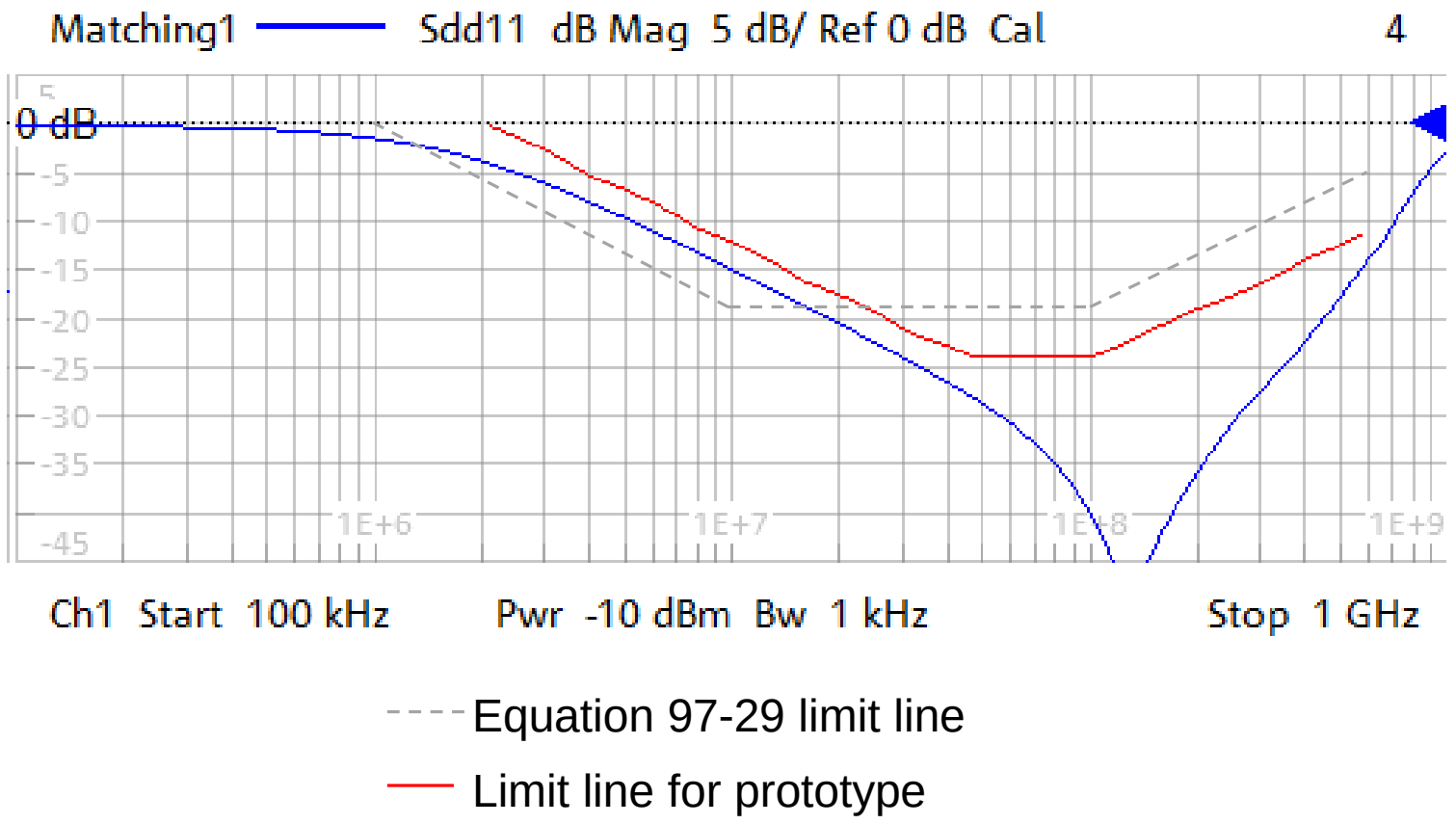
$$PoDL\ Prototype\ RL\ (dB) \geq \begin{cases} 18 - 18 \times log_{10}\left(\frac{20}{f}\right) & 2 \leq f < 43 \\ 24 & 43 \leq f < 100 \\ 24 - 16.7 \times log_{10}\left(\frac{f}{100}\right) & 100 \leq f < 600 \end{cases}$$

where f is frequency in MHz



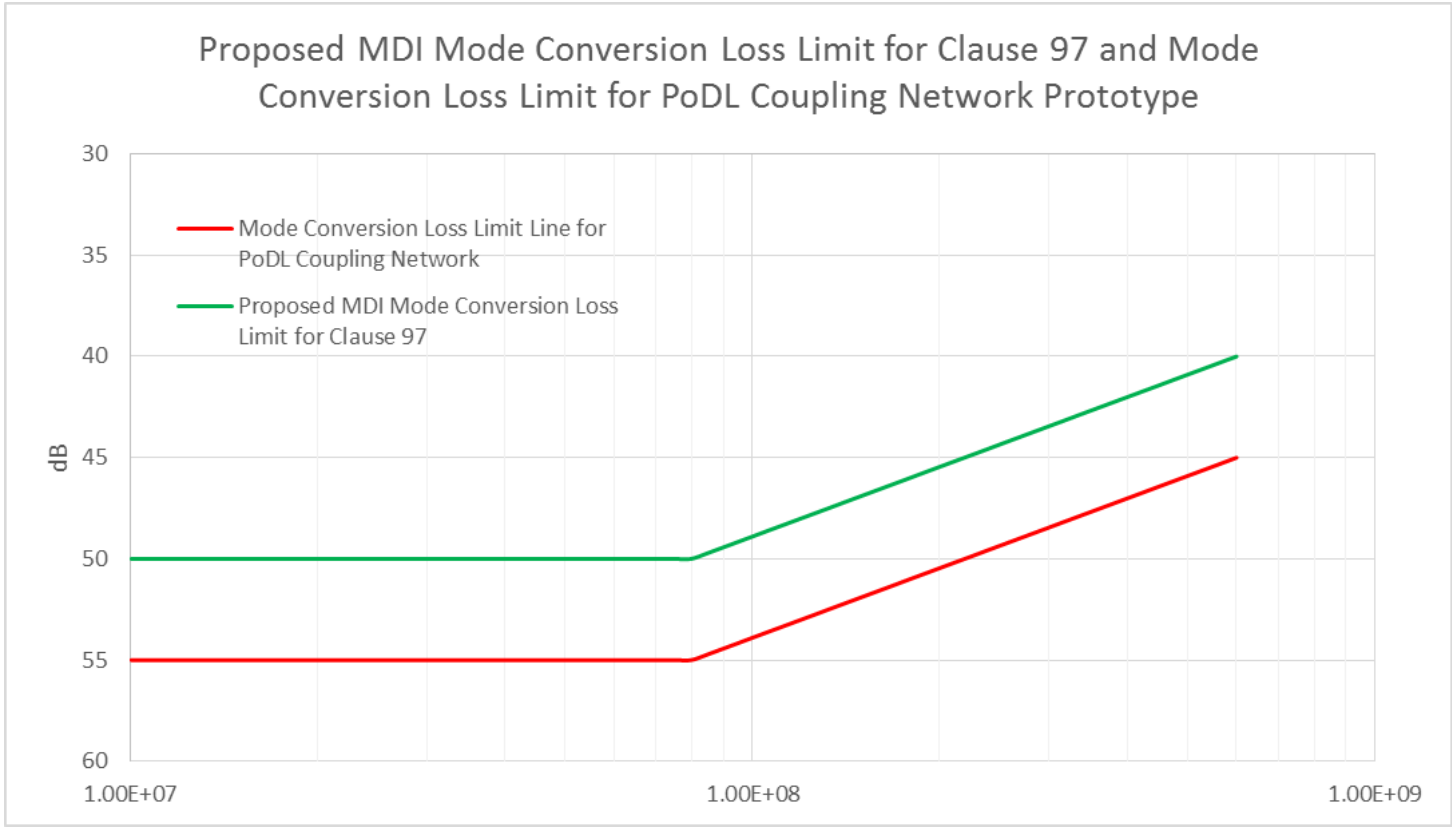
Measured Return Loss Data for PoDL Coupling Network Prototype

- Return loss limit was met by prototype, but compensation of the 1uH coupled inductors was required to meet the proposed spec up to 600MHz.
- Robustness of compensation technique needs to be verified over a statistically significant sample size.



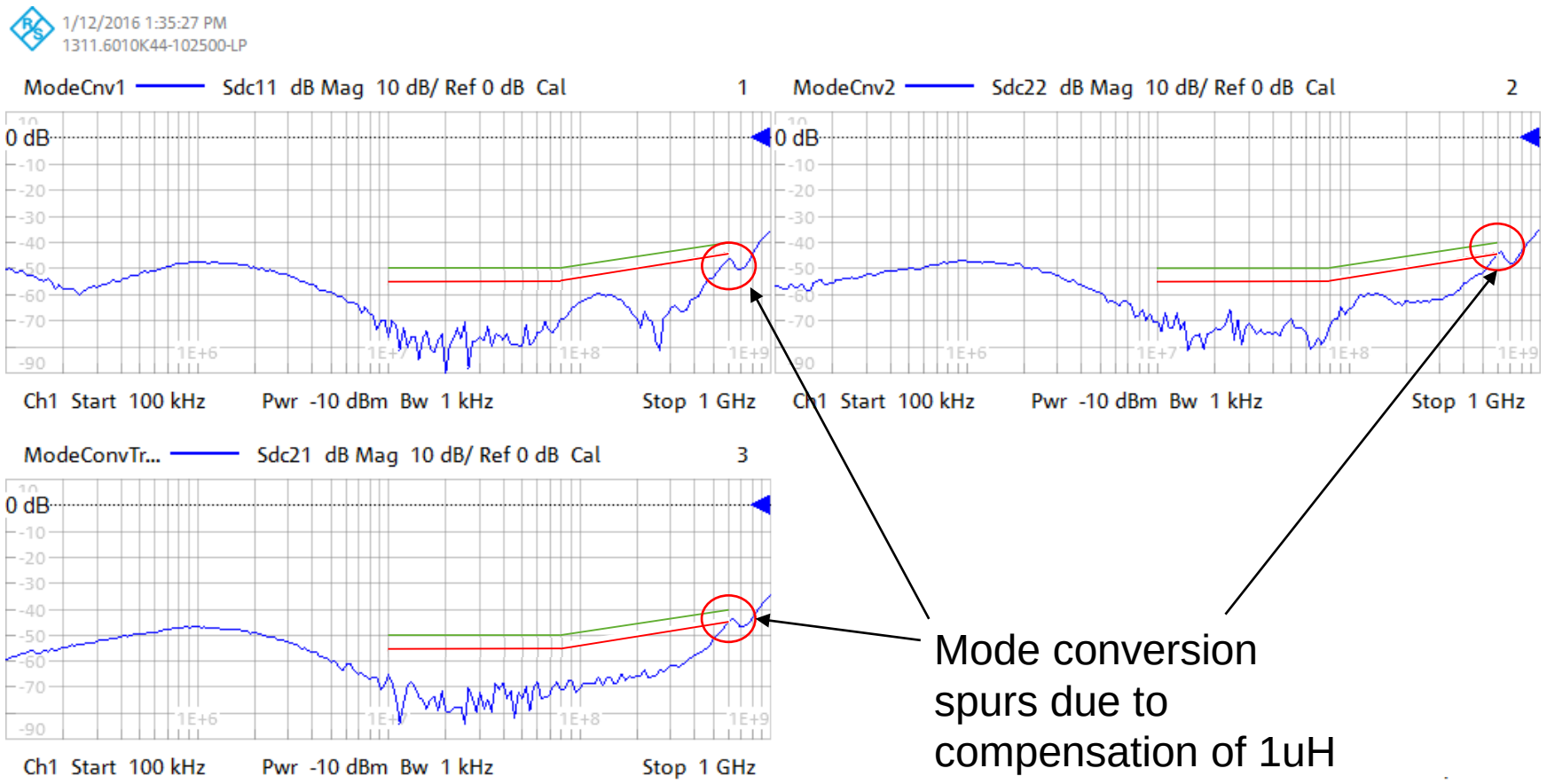
Proposed MDI Mode Conversion Loss Limit

- There currently is no MDI mode conversion loss limit in Clause 97.
- In order to ensure sufficient BER in a complete system, a MDI mode conversion limit copied from the Type A Link Segment Mode Conversion Loss Limit (Equation 97-18) is proposed.
- 5dB of margin was added to Equation 97-18 for the PoDL coupling network prototype mode conversion limit.



Measured Mode Conversion Loss Data for PoDL Coupling Network

- Proposed MDI mode conversion loss limit with 5dB of margin was met by prototype, but compensation of 1µH coupled inductor RL introduced spurs at 600MHz.
- Repeatability of the mode conversion loss performance needs to be verified over a statistically significant sample size.



Additional Areas for Prototype Investigation

- Convert test setup from SMA connectors and coax cables to UTP connectors and cables.
  - Performance may degraded by this conversion.
- Introduce DC bias into the coupling network in order to observe the effects on return loss and mode conversion loss.
- Build-up a statistically significant number of prototypes and characterize the subsequent distributions of mode conversion loss and return loss.
- Implement the PoDL coupling network as part of a working PHY MDI and measure the resulting performance.

Conclusions

- A PoDL coupling network prototype potentially suitable for use with 1000BASE-T1 PHYs was demonstrated.
- A proposed MDI return loss specification based on Equation 104-3 was met with margin.
  - Compensation of the 1uH coupled inductor's RL was required to stay under the limit at high frequencies, but this fix introduced spurs in the mode conversion loss at 600MHz.
- A proposed MDI conversion loss specification based on Equation 97-18 was met with margin.
  - There should be a MDI mode conversion loss specification in order to ensure adequate noise immunity for compliant PHYs.
- Additional relaxation of the low frequency MDI RL limit beyond 18dB at 20MHz may be required.
  - The mode conversion loss demonstrated by the prototype solution needs to be validated by a statistically significant sample size.

Proposals for IEEE P802.3bp

- Relax MDI return loss limit equation 97-29 as follows:

$$MDI\ RL\ (dB) \geq \begin{cases} 18 - 18 \times log_{10}\left(\frac{\sout{10}\ 20}{f}\right) & \sout{1}\ 2 \leq f < \sout{10}\ 20 \\ 18 & \sout{10}\ 20 \leq f < 100 \\ 18 - 16.7 \times log_{10}\left(\frac{f}{100}\right) & 100 \leq f < 600 \end{cases}$$

where f is frequency in MHz

- Add a MDI mode conversion loss limit to sub-clause 97.6:

$$\text{ConversionLoss}(f) \geq \left\{ \begin{array}{cc} 50 & 10 \leq f \leq 80 \\ 72 - 11.51 \times \log_{10} f & 80 < f \leq 600 \end{array} \right\} \text{ dB}$$

where f is frequency in MHz

Annex – Measured Insertion Loss of PoDL Prototype Coupling Network