Link Segment Baseline Proposal Industrial Applications IEEE 802.3 10 Mb/s Single Twisted Pair Ethernet Task Force

Huntington Beach, CA

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Purpose

- **Scope**
  - **Link Segment baseline proposal for Industrial Applications**

- **Rationale**
  - **Link segment baseline to address objectives and to generate first draft**

- **Link Segment**
  - **Developed in conjunction with the Industrial networking industries**

IEEE 802.3cg: Adopted Objectives

Objectives (2)

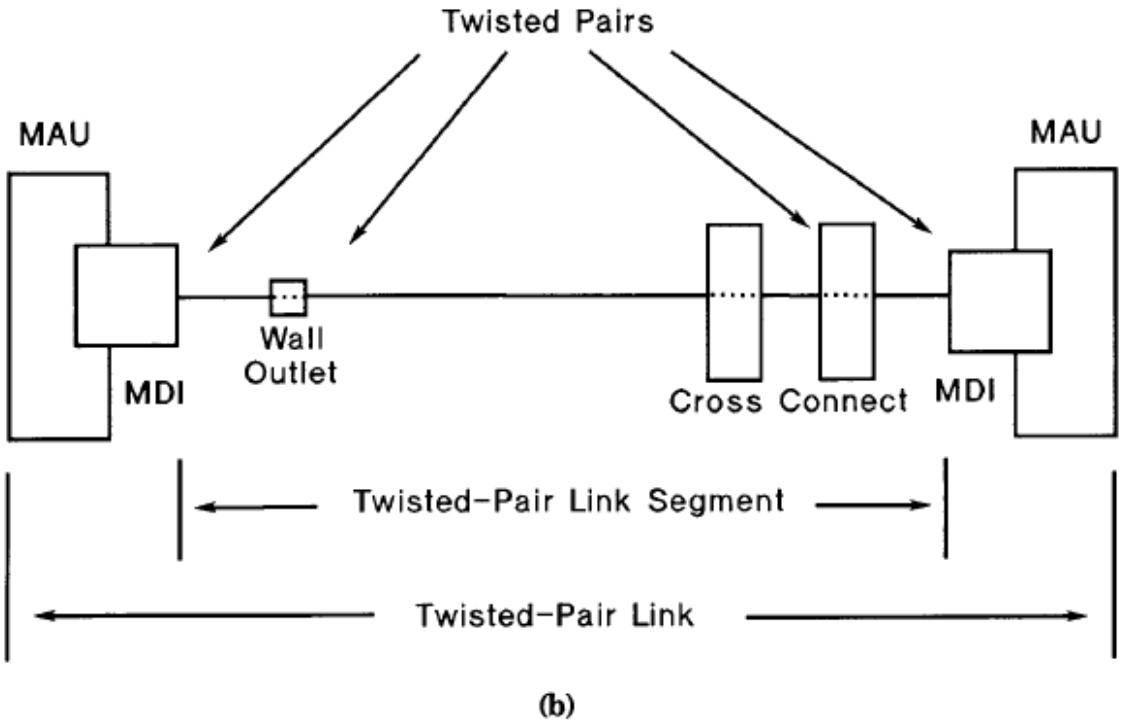
11. Define the performance characteristics of a link segment and a PHY to support operation over this link segment with single twisted pair supporting up to four inline connectors using balanced cabling for up to at least 15 m reach
12. Define the performance characteristics of a link segment and a PHY to support point-to-point operation over this link segment with single twisted pair supporting up to 10 inline connectors using balanced cabling for up to at least 1 km reach
13. Support fast-startup operation using predetermined configurations which enables the time from power_on**=FALSE to a state capable of transmitting and receiving valid data to be less than 100ms
14. Maintain a bit error ratio (BER) at the MAC/PLS service interface of less than or equal to 10^{-10} on link segments up to at least 15m, and 10^{-9} on link segments up to at least 1km
15. Specify one or more optional power distribution techniques for use over the 10 Mb/s single balanced twisted-pair link segments, in conjunction with 10 Mb/s single balanced twisted-pair PHYs, in the automotive and industrial environments

Source: http://www.ieee802.org/3/10SPE/objectives_10SPE_111016.pdf

Link Segment

1.4.242 link segment: The point-to-point full-duplex medium connection between two and only two Medium Dependent Interfaces (MDIs).

- **Example 10BASE-T**



(b)

Figure 14–2—Twisted-pair link

Link segment specifications

- Link Segment IL= Link Segment Cable IL + Link Segment connector IL + ILD channel
  - Link Segment Cable IL =(TBD coefficient)*(1.82*SQRT(f)+0.0091*f+0.25/SQRT(f))
  - Link Segment connector IL = 0.04*SQRT(f)
  - ILD channel (TBD)
  - Shielded cable, stranded copper condutors
  - Temperature dependencies (TBD - 70 deg C)
- Link Segment RL
  - Link Segment Cable 100 +/- 20%
  - Link connector RL = TBD from measured connectors
  - Model of concatenation of cables and connectors –configurations TBD
- Link Segment crosstalk
  - Link Segment measurements (TBD)
  - Cable, connector, measurements (TBD)
  - Shielding (alien crosstalk) (TBD)

Background:
http://www.ieee802.org/3/10SPE/public/Sept2016_Interim/diminico_01_0916.pdf
http://www.ieee802.org/3/10SPE/public/Nov2016/diminico_01b_1116.pdf

Link Segment Insertion Loss Specifications

- **Cable insertion loss – 20 deg C**

AWG	Diameter(in)	Diameter(mm)	dB/m at 4 MHz solid	dB/m at 4 MHz stranded	dB/m at 20 MHz solid	dB/m at 20 MHz stranded
14	0.064085	1.627754	0.013389	0.016067	0.029505	0.035407
15	0.057069	1.449551	0.015035	0.018042	0.033133	0.039759
16	0.050821	1.290858	0.016883	0.020260	0.037206	0.044647
17	0.045257	1.149538	0.018959	0.022751	0.041780	0.050136
18	0.040303	1.023689	0.021290	0.025548	0.046916	0.056299
19	0.035890	0.911618	0.023907	0.028688	0.052684	0.063221
20	0.031961	0.811816	0.026846	0.032215	0.059161	0.070993
21	0.028462	0.722941	0.030146	0.036175	0.066434	0.079720
22	0.025346	0.643795	0.033852	0.040623	0.074601	0.089521
23	0.022571	0.573314	0.038014	0.045617	0.083772	0.100526
24	0.020100	0.510549	0.042687	0.051225	0.094071	0.112885
25	0.017900	0.454655	0.047935	0.057522	0.105635	0.126762
26	0.015940	0.404881	0.053828	0.064594	0.118622	0.142346
27	0.014195	0.360555	0.060446	0.072535	0.133204	0.159845
28	0.012641	0.321083	0.067876	0.081452	0.149580	0.179496
29	0.011257	0.285931	0.076221	0.091465	0.167969	0.201563
30	0.010025	0.254628	0.085591	0.102710	0.188619	0.226342
31	0.008927	0.226752	0.096114	0.115336	0.211807	0.254168
32	0.007950	0.201928	0.107929	0.129515	0.237845	0.285414

*Reference IL =1.82*SQRT(f)+0.0091*f+0.25/SQRT(f)*

**commercially available specified to 500 MHz*
***~12% increase/decrese per gauge*
****20% increase for stranded*

Link Segment Cable IL (100m) = (0.28688)(1.2)*(1.82*SQRT(f)+0.0091*f+0.25/SQRT(f)*

guage size correction

20% Increase for stranded

Contribution on Channel Insertion Loss

Insertion loss

as presented in Rational for 1000m and Proposal for Objectives

J. Gottron L.Winkel 5 October 2016

1.2 Insertion loss

The insertion loss for the pair of a channel shall not exceed the limits computed, to one decimal place, using the formula of Table 2.

Table 2 – Formulae for insertion loss limits for a 1000 m channel

Frequency MHz	Maximum insertion loss
$1 < f \leq 20$	$10 * \left(1{,}23\sqrt{f} + 0{,}01f + 0{,}2/\sqrt{f}\right) + 10 \times 0{,}015\sqrt{f}$

Note: to be deleted before publication. ILD is marginal for this frequencies.

Cable IL (100 m) = 10(1.23*SQRT(f)+0.01*f+0.2/SQRT(f))*

*Connector IL (10 connectors) = 10*0.015 *SQRT(f)*

Connector values even lower as presented by Chris Diminico in San Antonio

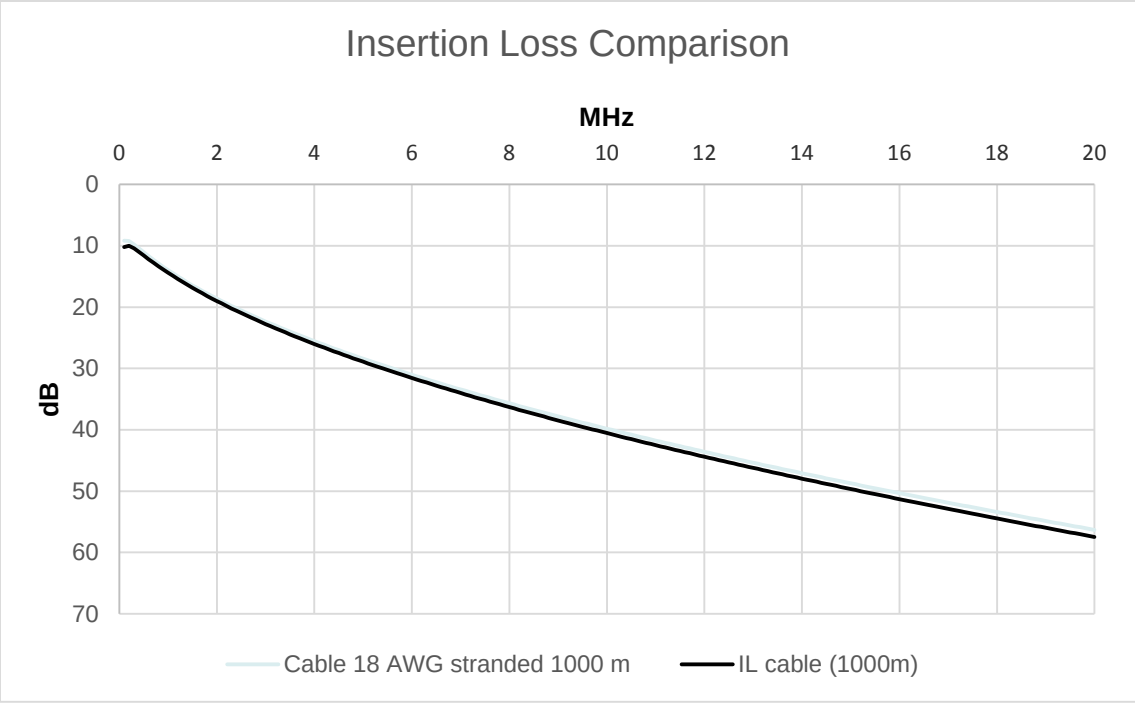
Source: http://www.ieee802.org/3/10SPE/public/adhoc/Fritsche_Schicketanz_121416_10SPE_01a_ad%20hoc.pdf

Cable insertion loss comparison

- *Cable IL (100 m) = (1.223*SQRT(f)+0.006*f+0.168/SQRT(f)*
- *Cable IL (1000 m) = 10*(1.223*SQRT(f)+0.006*f+0.168/SQRT(f))*

•*Source: http://www.ieee802.org/3/10SPE/public/adhoc/Fritsche_Schicketanz_121416_10SPE_01a_ad%20hoc.pdf*

  – *Cable IL (1000 m) = 10*(1.23*SQRT(f)+0.01*f+0.2/SQRT(f))*



Category Cabling IL

	Frequency (MHz)	Insertion loss (dB)
Category 3	$1 \le f \le 16$	$0.10\sqrt{f}$
Category 5e	$1 \le f \le 100$	$0.04\sqrt{f}$
Category 6	$1 \le f \le 250$	$0.02\sqrt{f}$
Category 6A	$1 \le f \le 500$	$0.02\sqrt{f}$

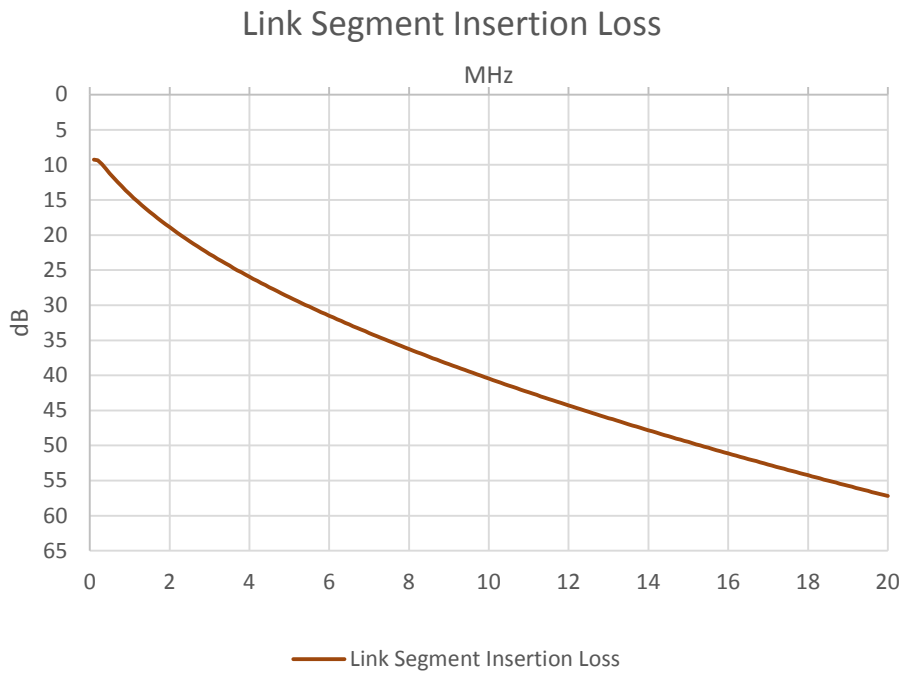
Connector measurements IL < 0.02 dB
100 KHz ≤ f ≤ 20 MHz

Link Segment Insertion Loss Proposal

- The link segment shall meet the values determined using Equation (xx) dB

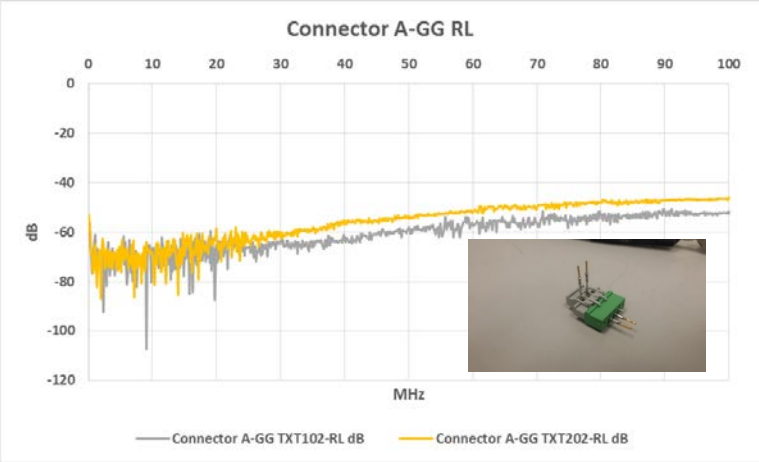
Insertion Loss (f) ≤ 10(1.23*SQRT(f)+0.01*f+0.2/SQRT(f))+10*(0.02*sqrt(f)) (dB)*

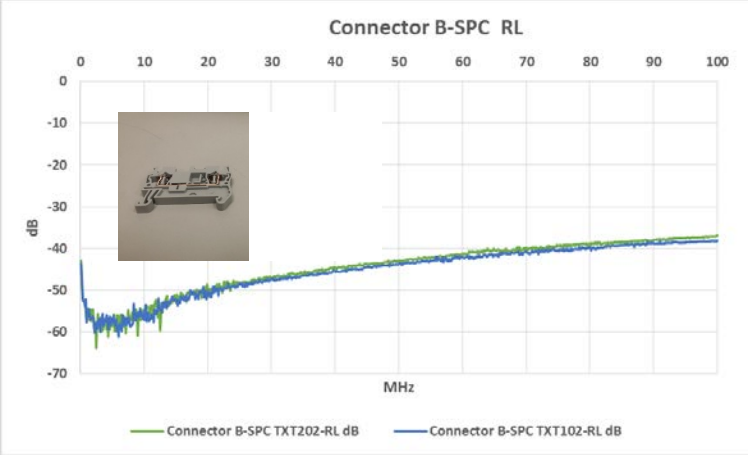
where
f is the frequency in MHz; [1(TBD) MHz to 20 (TBD) MHz]

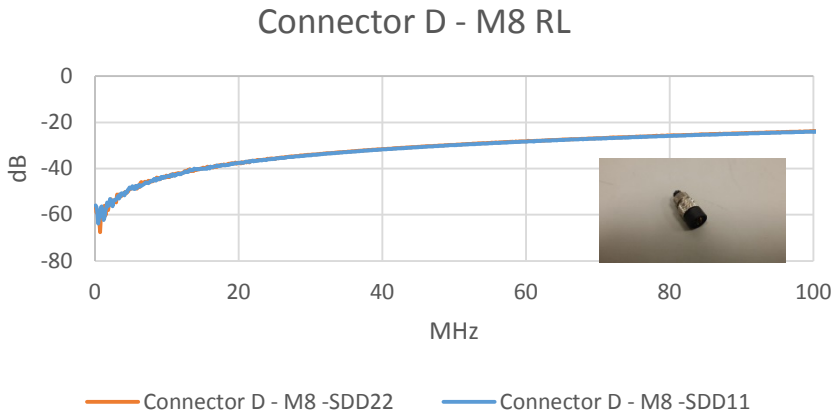


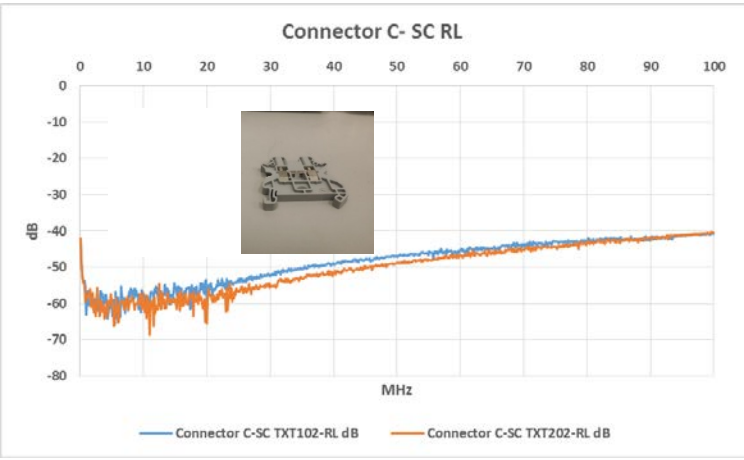
25.95 dB @ 4 MHz

Connector Return Loss Measurements









Background:
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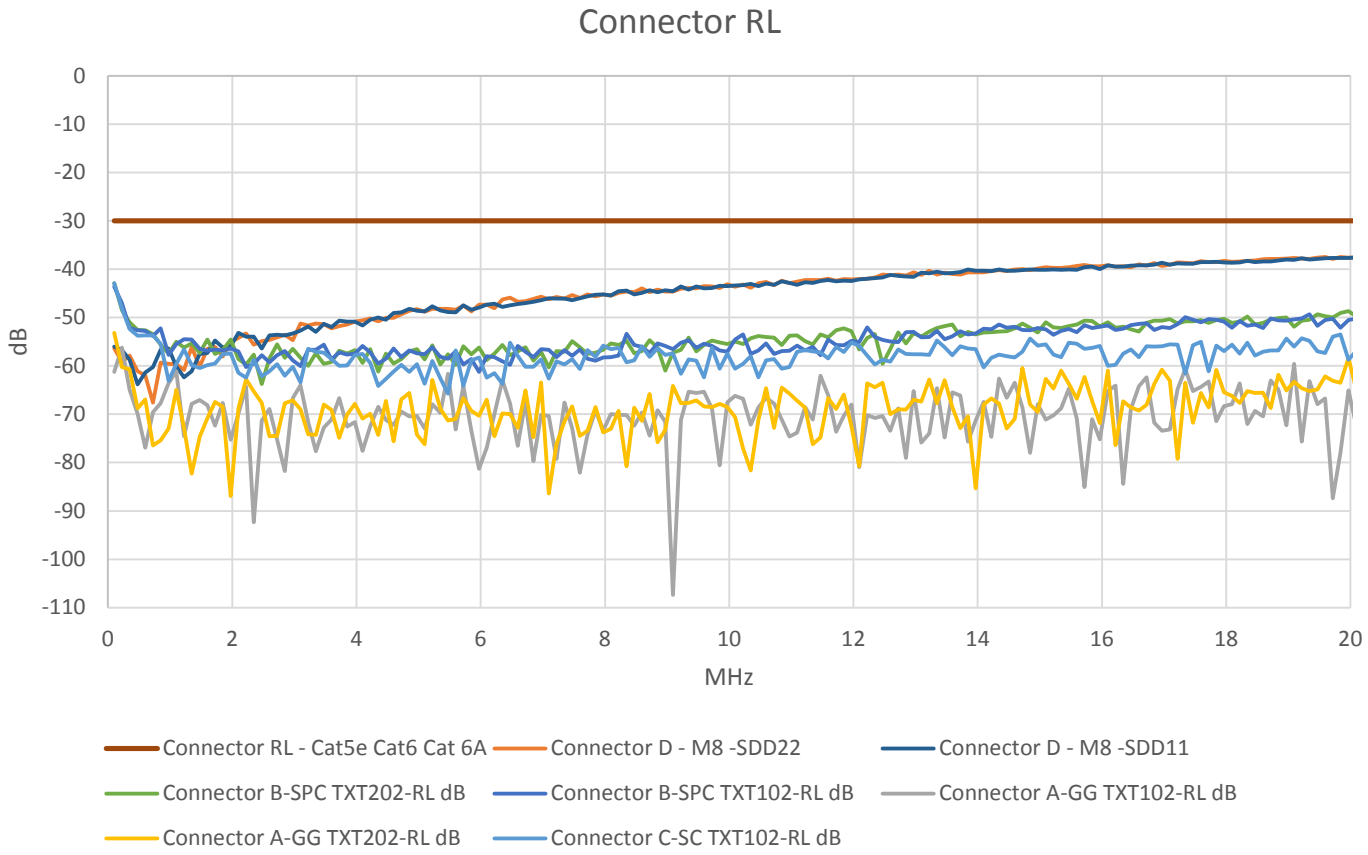
IL < 0.02 dB
100 KHz ≤ f ≤ 20 MHz

Connector Return Loss Measurements



IL < 0.02 dB
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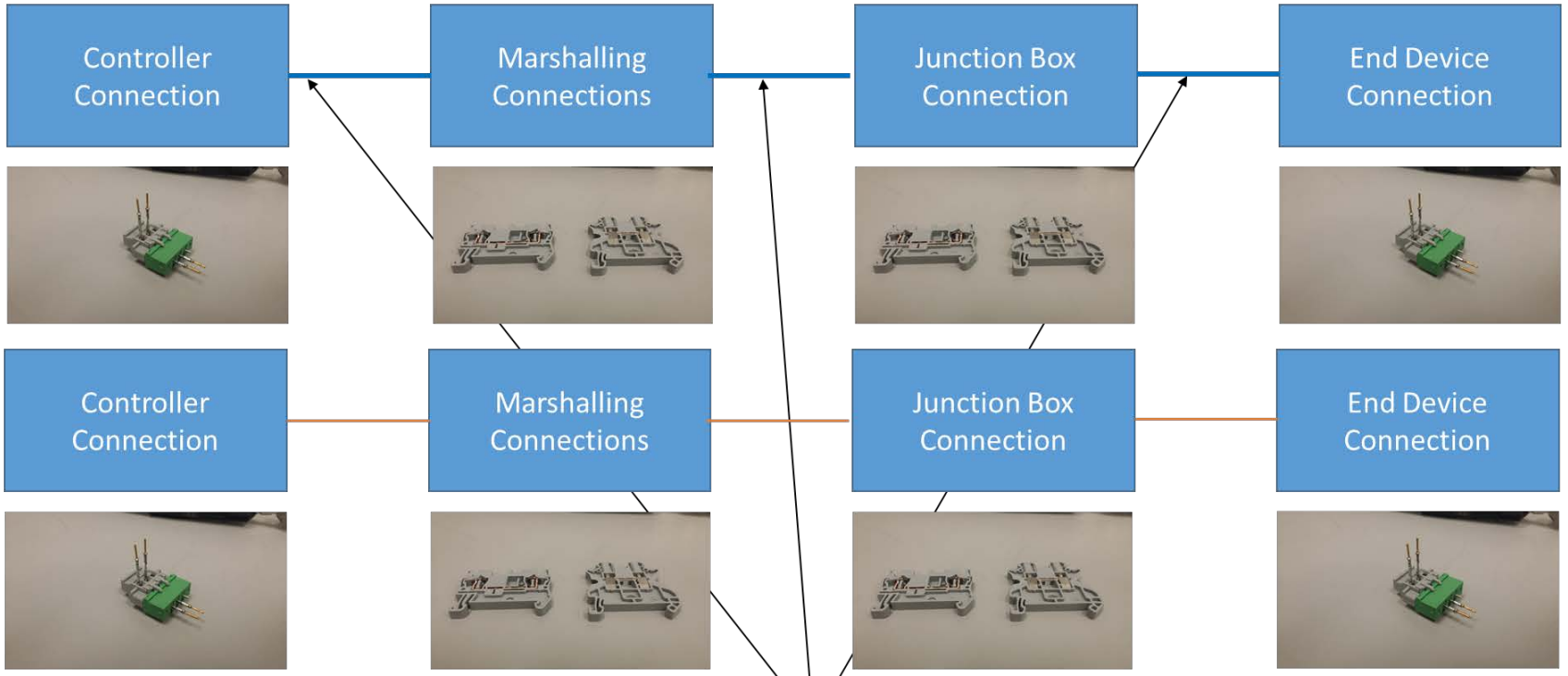
http://www.ieee802.org/3/10SPE/public/Nov2016/diminico_01b_1116.pdf

Link Segment Measurements

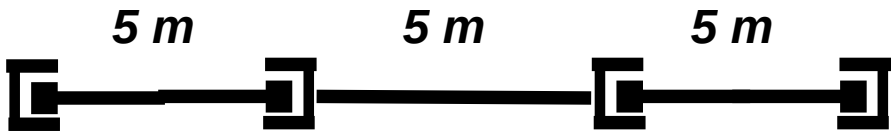
MEASURED CONFIGURATION

CHANNEL 1 (Blue Pair)



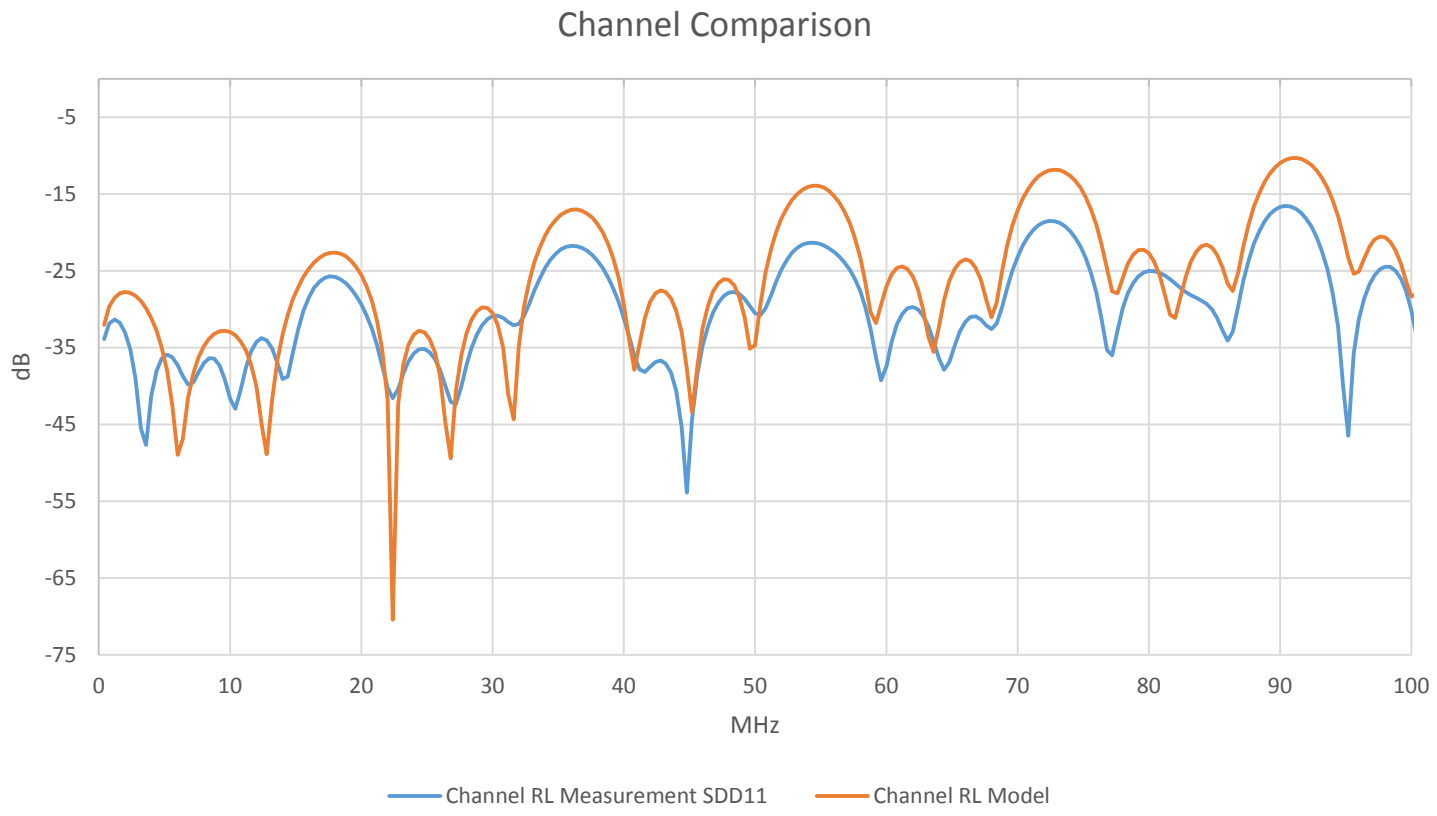
CHANNEL 2 (Orange Pair)

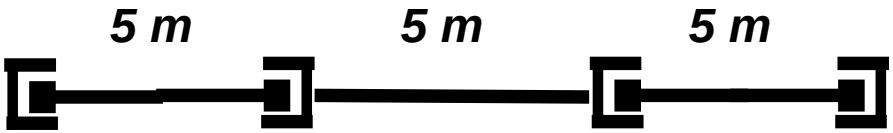
5 meter lengths of 23+ AWG twisted pair harvested from Category 8 cable, 3 places



Link Segment RL Model

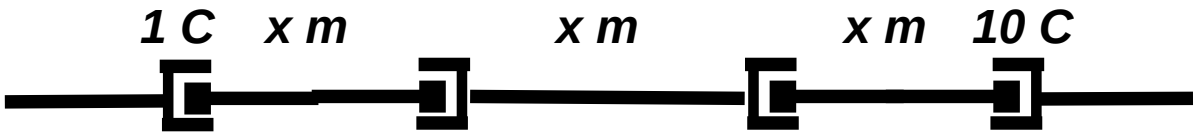
- Cascade ABCD matrices of connectors and cables





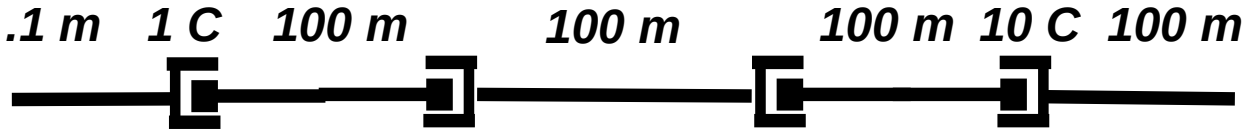
Link Segment RL Model

- 10 connectors separated by 10, 20,30,100 meters
- All cables 100 ohms



X=10, 20,30,100 meters
10 connectors, 11 cable lengths

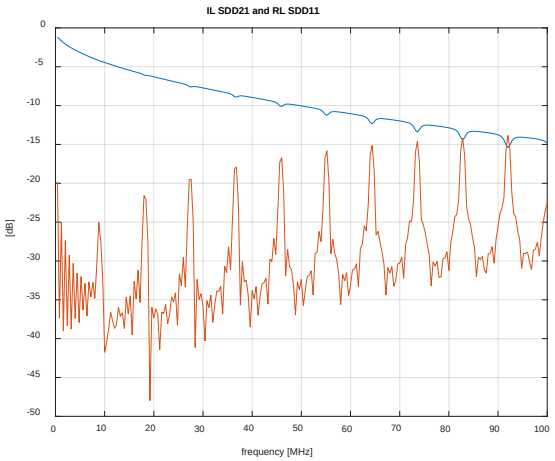
- 10 connectors separated by 100 meters
- All cables 100 ohms



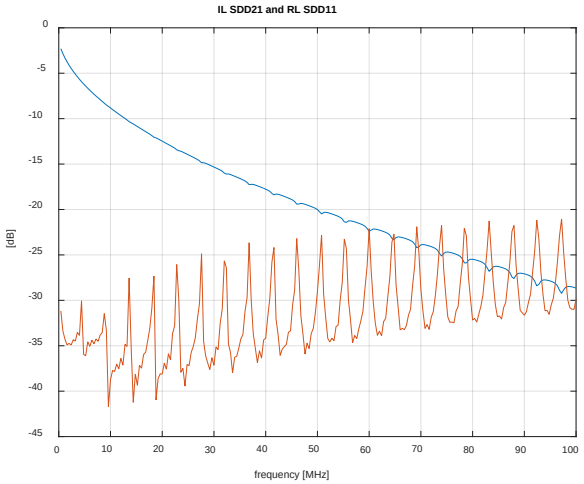
Link Segment RL Model

- 10 connectors separated by 10, 20,30,100 meters

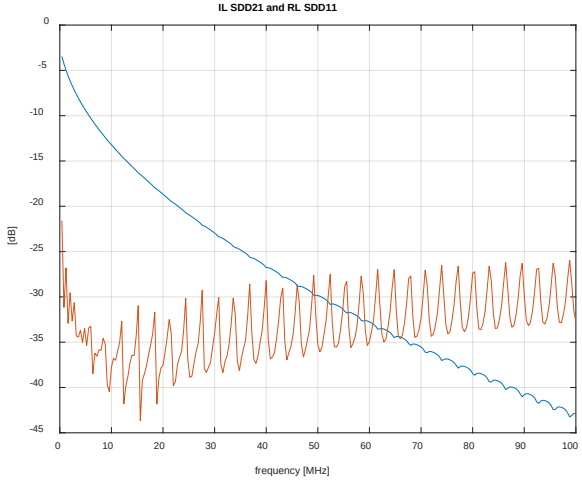
10 meters



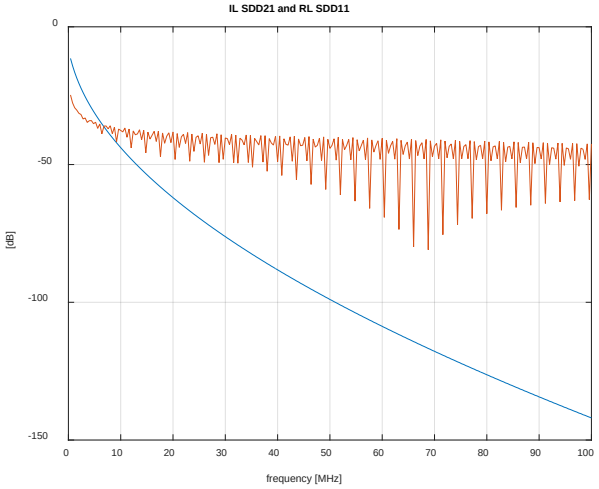
20 meters



30 meters

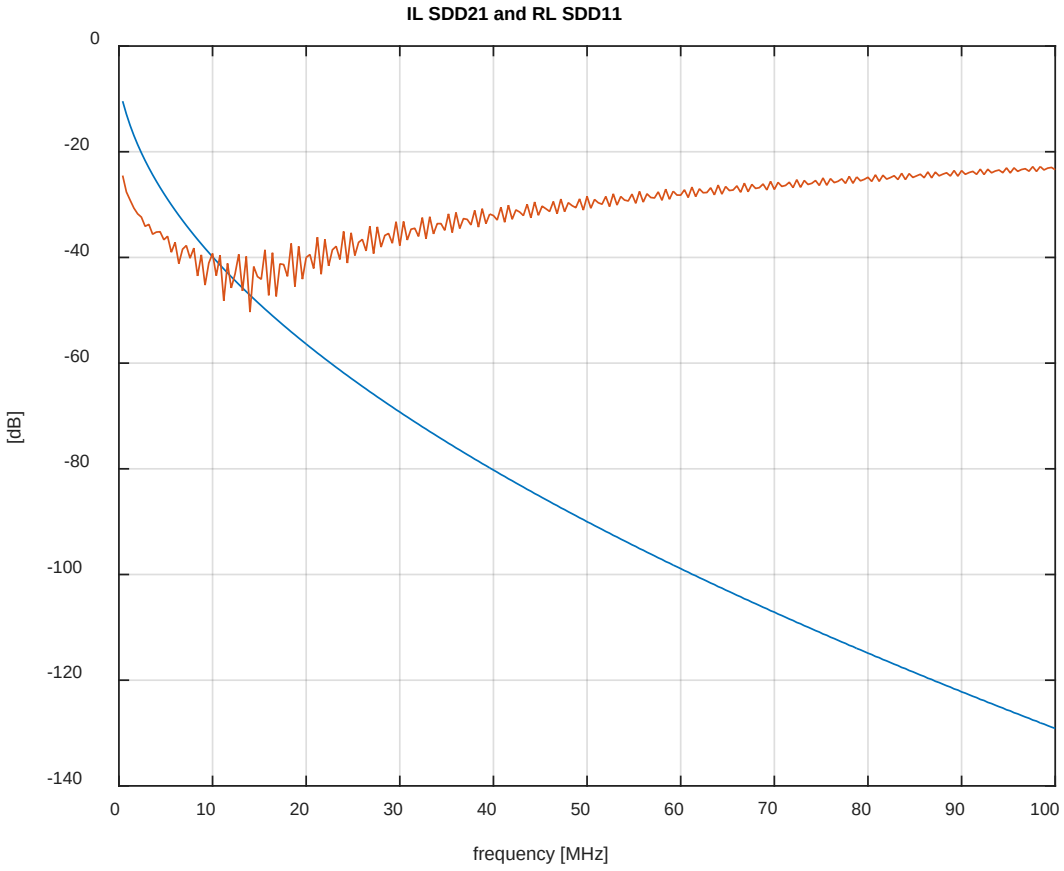


100 meters



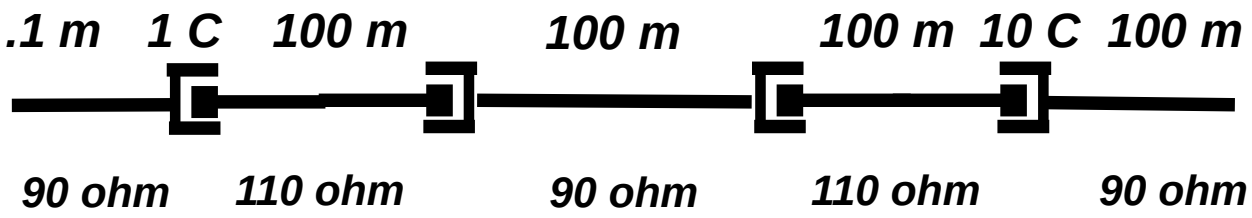
Link Segment RL Model

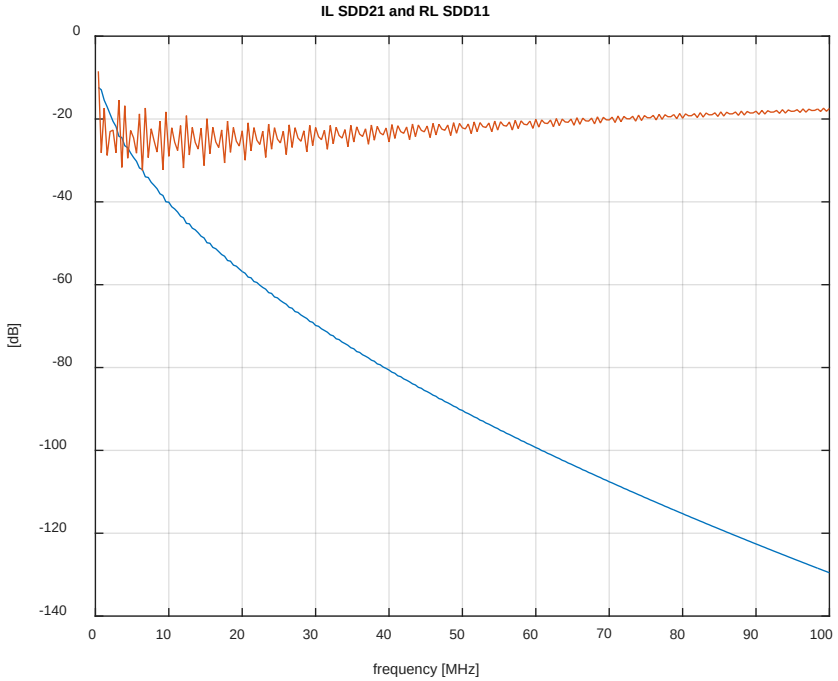
- 10 connectors separated by 100 meters
- .1 m cable at input



Link Segment RL Model

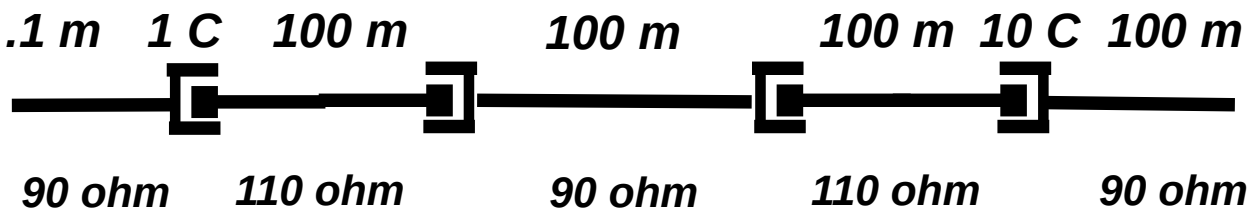
- 10 connectors separated by 100 meters
- Cables +/- 10%

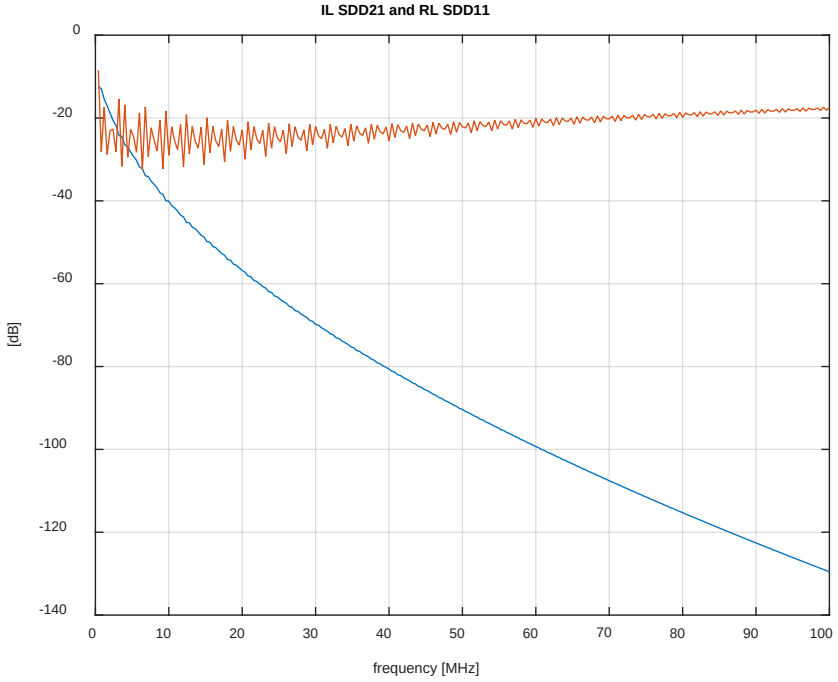




Link Segment RL Model

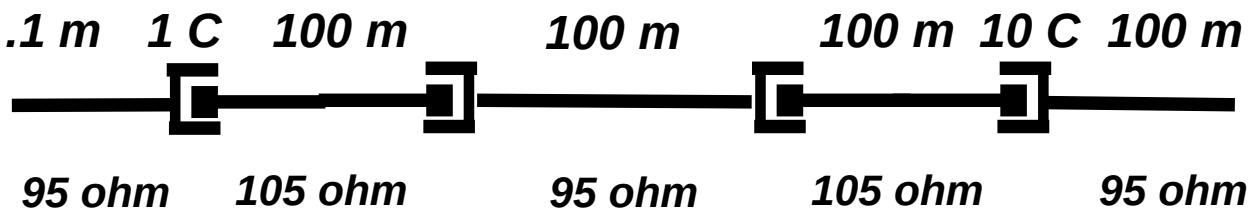
- 10 connectors separated by 100 meters
- Cables +/- 10%

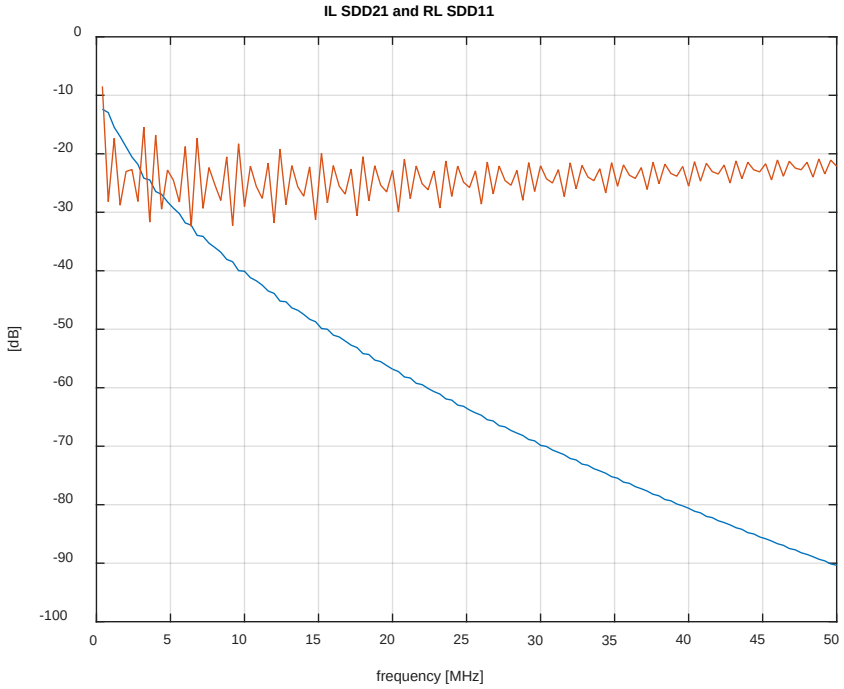




Link Segment RL Model

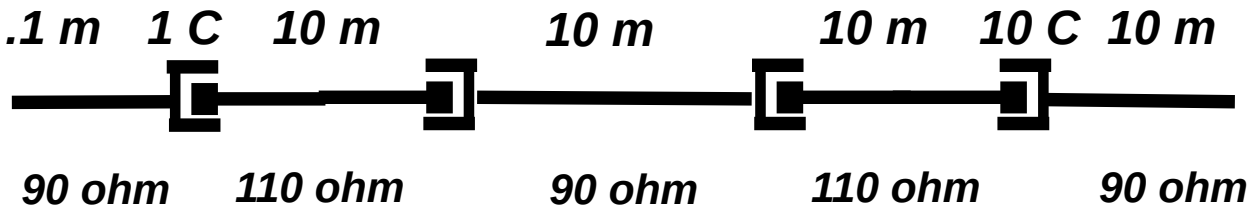
- 10 connectors separated by 100 meters
- Cables +/- 5%

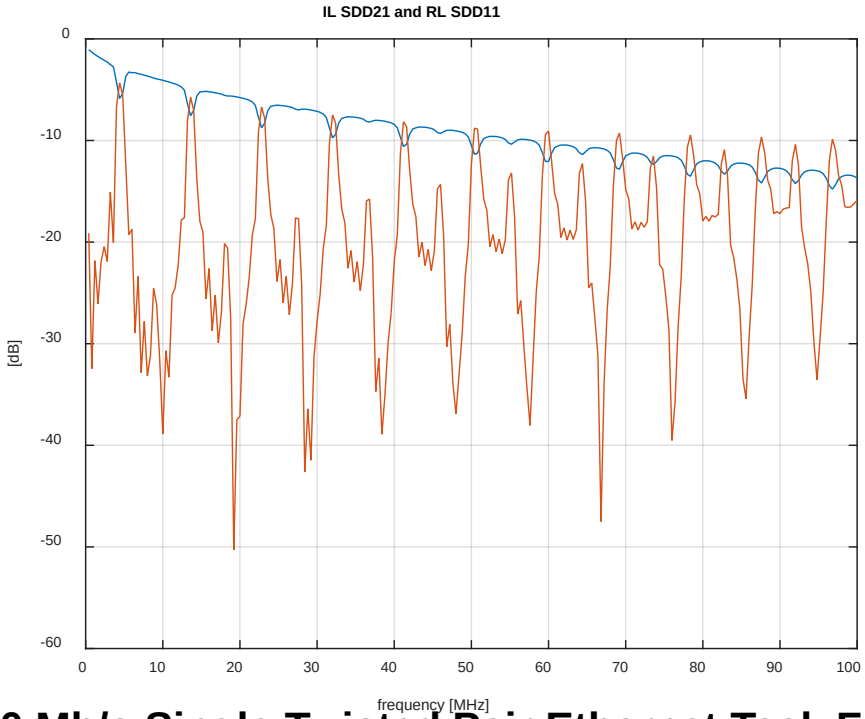




Link Segment RL Model

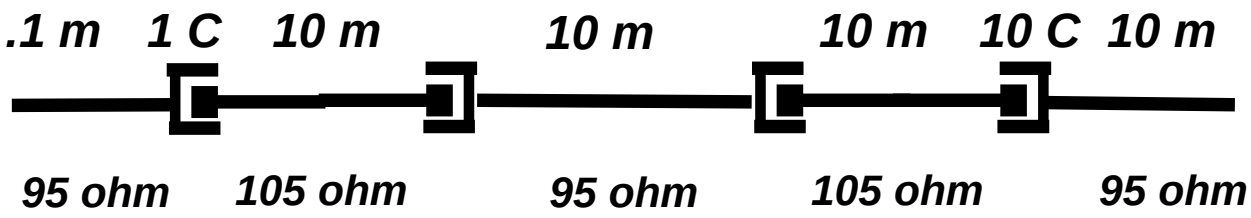
- 10 connectors separated by 10 meters
- Cables +/- 10%

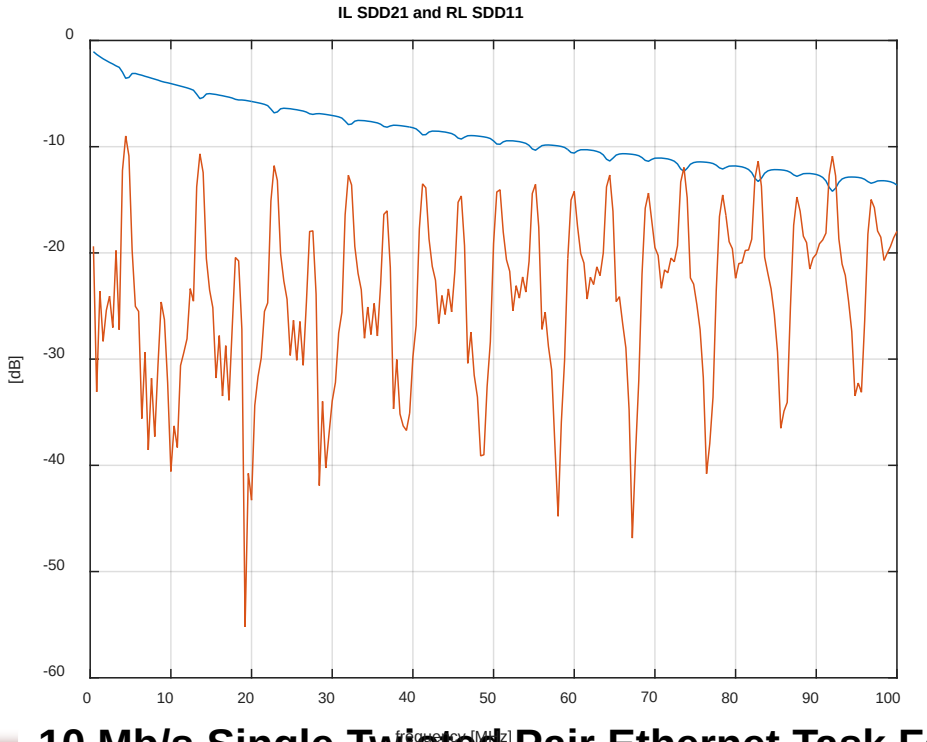




Link Segment RL Model

- 10 connectors separated by 10 meters
- Cables +/- 5%





Contribution on Channel RL

Return loss

1.1 Return loss

The return loss for the pair of a channel shall not exceed the limits computed, to one decimal place, using the formula of Table 1.

Table 1– Formula for return loss limits of a channel

Frequency MHz	Minimum return loss dB
$1 \le f \le 20$	19,0

The number of connection allowed is related to the link length:

- 10 connectons up to 1000m
- 8 connectons up to 750m
- 6 connectons up to 500m
- 4 connectons up to 200m

Note: This low value for return loss is to take care of cables with low impedance

•*Source: http://www.ieee802.org/3/10SPE/public/adhoc/Fritsche_Schicketanz_121416_10SPE_01a_ad%20hoc.pdf*

Category Cabling Channel RL

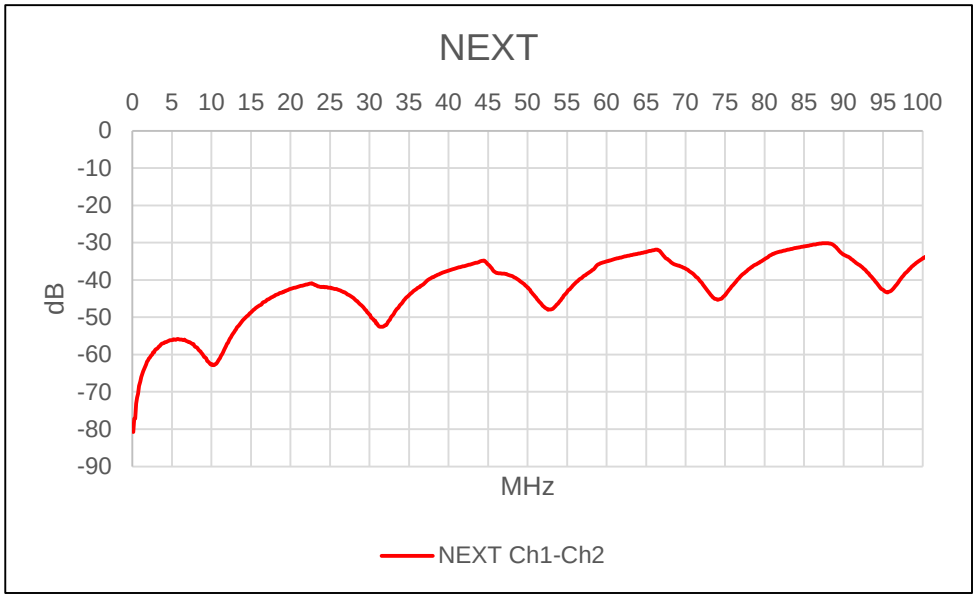
	Frequency (MHz)	Return loss (dB)
Category 3	$1 \le f \le 16$	n/s
Category 5e	$1 \le f < 20$ $20 \le f \le 100$	17 $17 - 10\log(f/20)$
Category 6	$1 \le f < 10$ $10 \le f < 40$ $40 \le f \le 250$	19 $24-5\log(f)$ $32-10\log(f)$
Category 6A	$1 \le f < 10$ $10 \le f < 40$ $40 \le f < 398.1$ $398.1 \le f \le 500$	19 $24-5\log(f)$ $32-10\log(f)$ 6

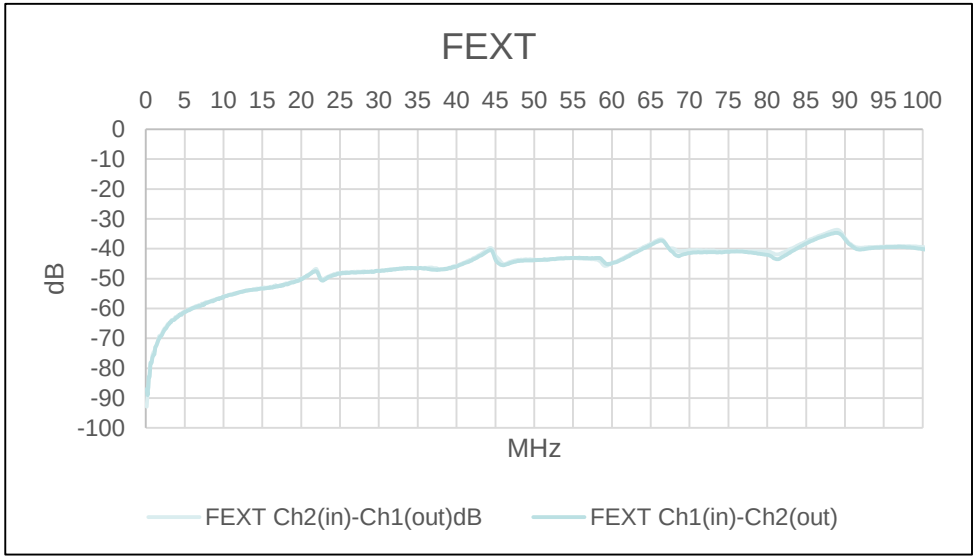
Link Segment Return Loss Proposal

- The link segment shall meet the value in Equation (xx) at all frequencies from 1(TBD) MHz to 20 (TBD) MHz. The reference impedance for the return loss specification is 100 ohms.

Return Loss (f) ≥ 19 dB [1(TBD) MHz to 20 (TBD) MHz]

Alien Crosstalk Link Segment Measurements





Summary

- **Link segment considerations for industrial applications**
  - **Insertion Loss Proposal**
  - **Return Loss Proposal**
  - **Alien Crosstalk - TBD**