Link Segment Characteristics
IEEE 802.3 10 Mb/s Single Twisted Pair Ethernet Study Group

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Purpose

- Scope
  - Initiate discussion(s) on 10 Mb/s Single Twisted Pair Ethernet Link Segment Specifications
    - Automotive
    - Industrial Automation

- Rationale
  - Link segment characteristics enables considerations for PHY (e.g., signaling)

- Link Segment
  - Developed in conjunction with the automotive/Industrial networking industries

Link Segment

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

- **10BASE-T**

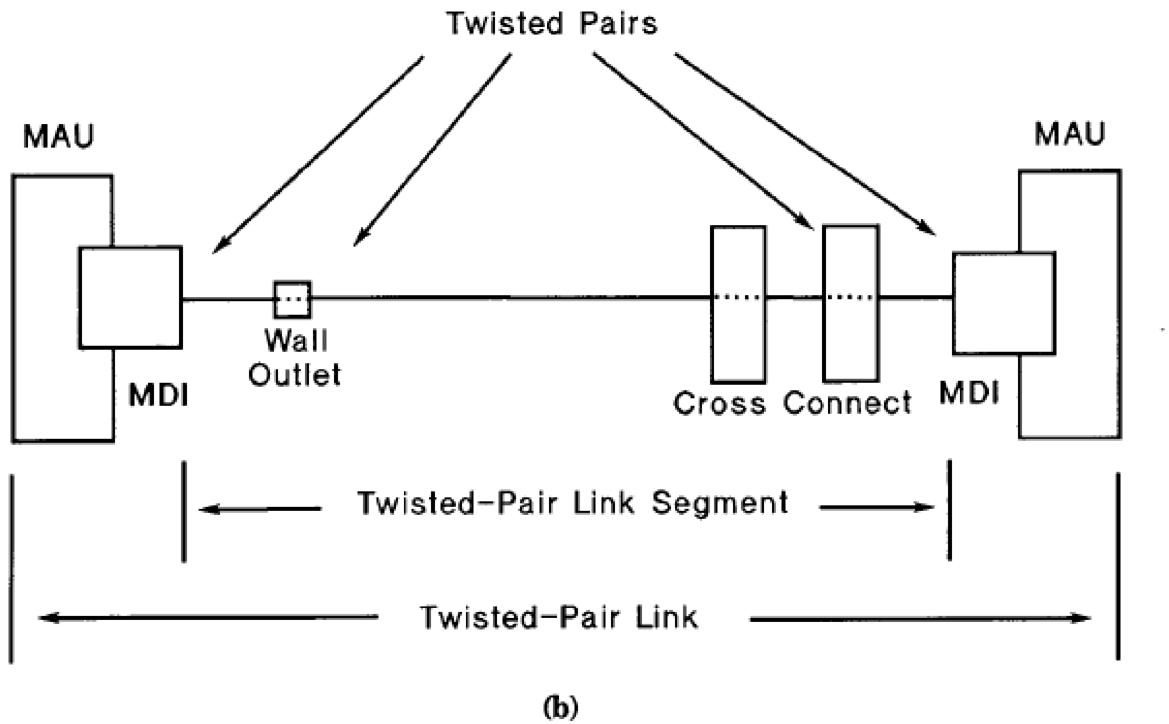
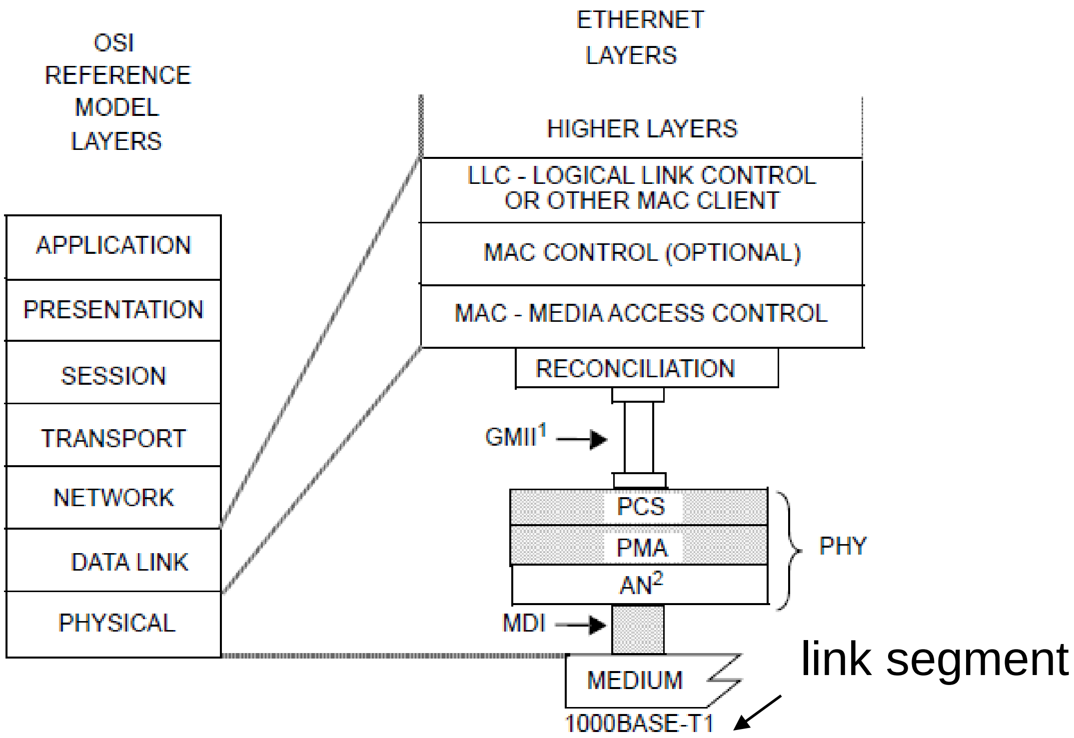


Figure 14–2—Twisted-pair link

1000BASE-T1 Link Segment



MDI = MEDIUM DEPENDENT INTERFACE
GMII = TEN GIGABIT MEDIA INDEPENDENT INTERFACE

NOTE 1—GMII is optional
NOTE 2—Auto-Negotiation is optional

PCS = PHYSICAL CODING SUBLAYER
PMA = PHYSICAL MEDIUM ATTACHMENT
PHY = PHYSICAL LAYER DEVICE
AN = AUTO-NEGOTIATION

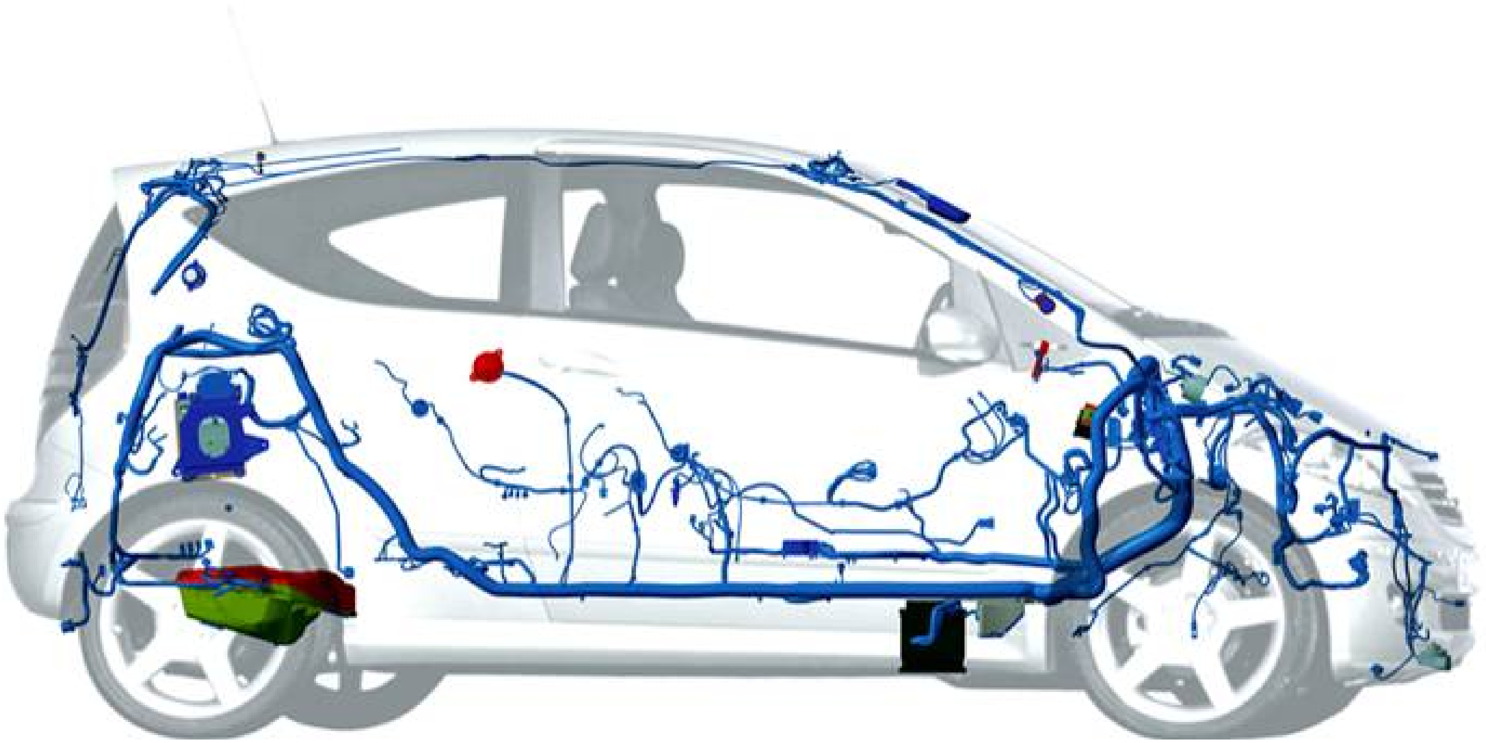
Automotive wiring system

Automotive wiring system example

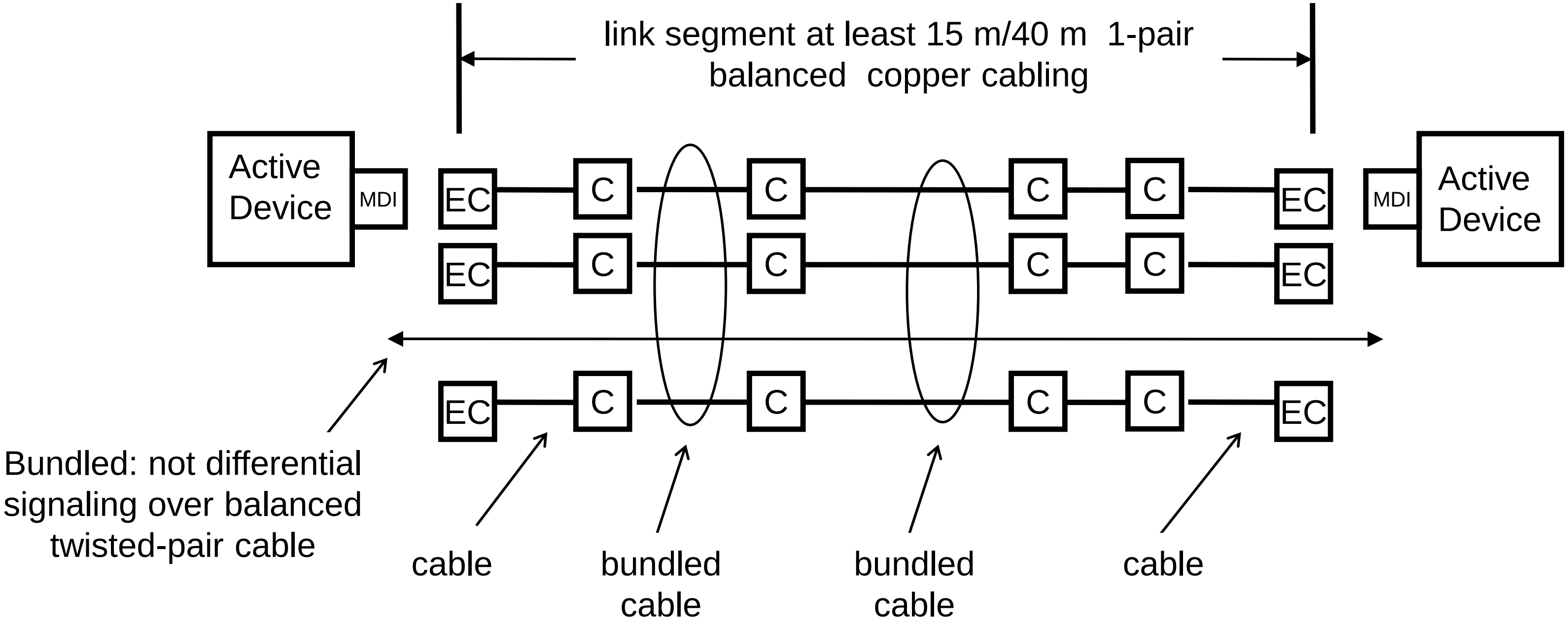
- Length of cable: more than 3 km
- Number of single cables : up to 1,500
- Number of contacts: up to 3,000
- Weight: up to 50 kg

Automotive versus LAN cabling

- Topology (identification of link segment)
- Temperature ratings (engine compartments)
- Jacketing and insulation materials (resistant to oil, gasoline, hydraulic fluids etc.)
- Mechanical properties



802.3bp Link Segment Representation



The IEEE 802.3 nomenclature is bracketed to identify relationship to the IEEE 802.3 definitions.

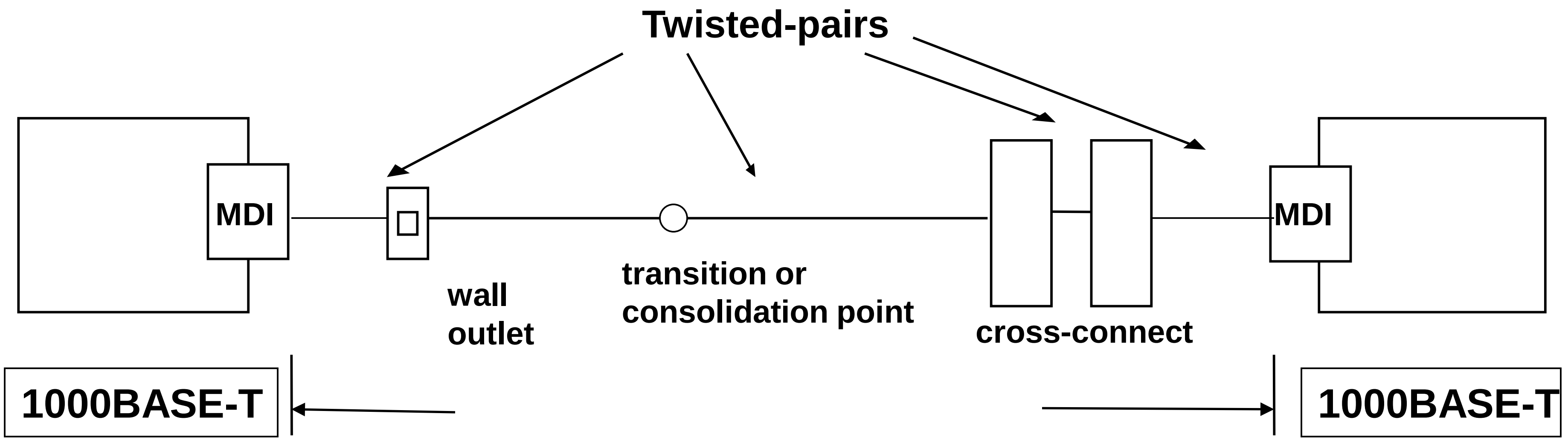
Length objective [EC] to [EC] at least 15 m/40 m
Number of inline connectors [C] = 4

C = inline connector

EC = connection to equipment

MDI = Active electronics connector [Medium dependent interface (MDI)]

Twisted Pair Link Segment



Structured cabling ISO/IEC, TR42

1000BASE-T Link transmission and coupling parameters

- **Insertion loss, Return loss**
- **NEXT, FEXT, Multiple Disturber Crosstalk**

1000BASE-T1 Link Segment

97.6 Link segment characteristics

1000BASE-T1 is designed to operate over a single twisted-pair copper cable that meets the requirements specified in this subclause. The single twisted-pair copper cable supports an effective data rate of 1 Gb/s in each direction simultaneously. The term “link segment” used in this clause refers to a single twisted-pair copper cable operating in full duplex.

Two link segments are specified:

a) A link segment optimized for use in automotive applications that supports up to four in-line connectors using a single twisted-pair copper cable for up to at least 15 m. This link segment is referred to as *link segment type A*.

b) An *optional link segment* supporting up to four in-line connectors using a single twisted-pair copper cable for up to at least 40 m to support applications requiring additional physical reach, such as industrial and automation controls and transportation (aircraft, railway, bus and heavy trucks). This link segment is referred to as *link segment type B*.

1000BASE-T1 Link Segment

- 97.6 Link segment characteristics
  - 97.6.1 Link transmission parameters for link segment type A
    - 97.6.1.1 Insertion loss
    - 97.6.1.2 Differential characteristic impedance
    - 97.6.1.3 Return loss
    - 97.6.1.4 Differential to common mode conversion
    - 97.6.1.5 Maximum link delay
  - 97.6.2 Link transmission parameters for link segment type B
    - 97.6.2.1 Insertion loss
    - 97.6.2.2 Differential characteristic impedance
    - 97.6.2.3 Return loss
    - 97.6.2.4 Maximum link delay
    - 97.6.2.5 Coupling attenuation

1000BASE-T1 Link Segment

- **Between Link Segments (Alien)**

- 97.6.3 Coupling parameters between type A link segments
  - 97.6.3.1 Multiple disturber alien near-end crosstalk (MDANEXT) loss
  - 97.6.3.2 Multiple disturber power sum alien near-end crosstalk (PSANEXT) loss
  - 97.6.3.3 Multiple disturber alien far-end crosstalk (MDAFEXT) loss
  - 97.6.3.4 Multiple disturber power sum alien attenuation crosstalk ratio far-end (PSAACRF)
- 97.6.4 Coupling parameters between type B link segments
  - 97.6.4.1 Multiple disturber alien near-end crosstalk (MDANEXT) loss
  - 97.6.4.2 Multiple disturber power sum alien near-end crosstalk (PSANEXT) loss
  - 97.6.4.3 Multiple disturber alien far-end crosstalk (MDAFEXT) loss
  - 97.6.4.4 Multiple disturber power sum alien attenuation crosstalk ratio far-end (PSAACRF)

Link segment/PHY - Considerations

- Topology
- Transmission and coupling parameters
- Environmental

- Topology
  - Length (up to at least x meters)
  - Number of connectors (x)

- Transmission and coupling parameters
  - Insertion loss
  - Link segment noise
    - o Noise within link segment –
      - ✓ return loss
      - ✓ mode conversion (balance)
    - o Noise coupling between link segments
      - ✓ Alien crosstalk - ANEXT, AFEXT and multiple disturber ANEXT and AFEXT
    - o Mode conversion (balance)

Link segment/PHY - Considerations

- 10 Mb/s Single-Pair PHY electromagnetic environment
  - Susceptibility levels
    - o Sources of interference from the environment (TBD)…
      - Emission levels External noise - noise from signaling or power in adjacent wire pairs from non-10 Mb/s Single-Pair PHYs

    - oThe twisted-pair link segment shall comply with applicable local and national codes for the limitation of electromagnetic.

- 10 Mb/s Single-Pair PHY operating environmental
  - Specific requirements for temperature, humidity and values for these parameters are considered to be beyond the scope of the 10 Mb/s Single-Pair PHYs specification. (informative annex?)
  - Specific requirements for physical stress (such as shock and vibration) and values for these parameters are considered to be beyond the scope of the 10 Mb/s Single-Pair PHYs (informative annex?)

- 10 Mb/s Single-Pair PHY MDI specifications
  - MDI electrical specifications (TBD)
  - Mechanical interface (non-objective (?)

IA Twisted Pair Link Segment

- Enables cable reuse
  - Installed base of Single Twisted Pair, usually shielded
  - Certain cables are certified
  - Lengthy fieldbus cables are expensive to install (often in filled conduit)
  - End nodes are easier to replace
  - Similar value proposition to 2.5G/5GBASE-T Task Force
- Enables constrained form factor applications (sensors etc.)
  - Reduced size and cost

High Cable Reuse Value

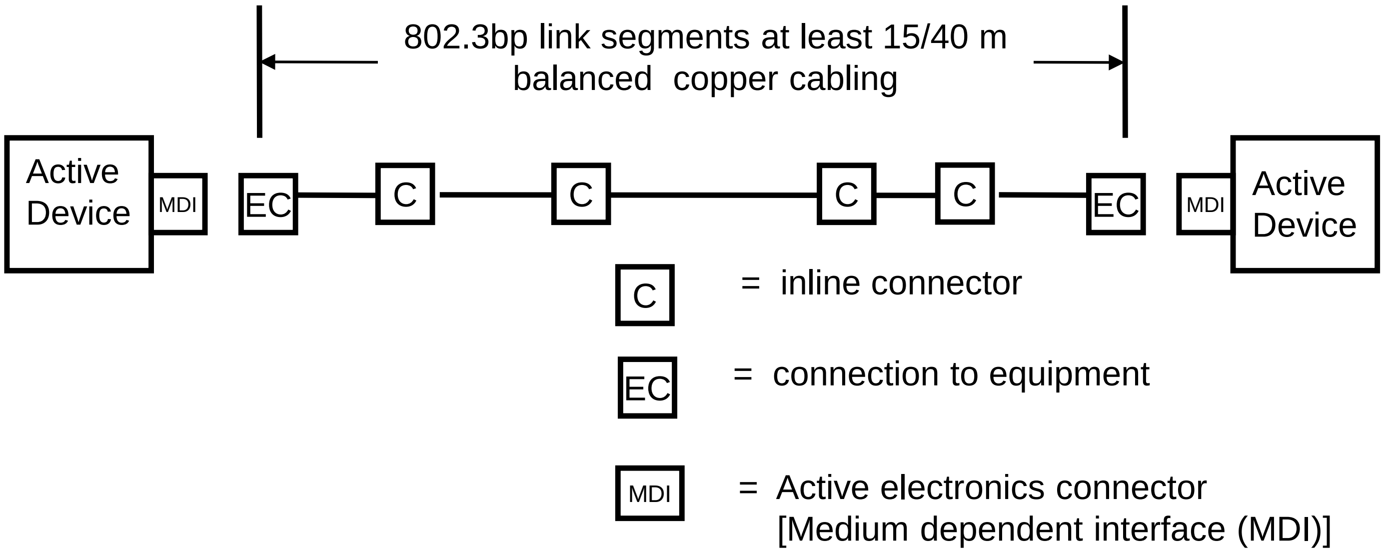
Fieldbus	Cable Type	Cable Power
FOUNDATION H1	FF-844 specified	Yes
HART	Various	Yes
PROFIBUS PA	IEC 61158 Type A	Yes
4-20mA	SP-50 instrumentation cable	Yes
CANopen	EIA-485	Yes
Modbus RTU	EIA-485	No
CC-Link	CC-Link, Ver.1.10 specified Shielded, 3- & 5-core	No
DeviceNet	ODVA DeviceNet specified (5-core, various classes)	Yes
ControlNet	RG-6/U Coaxial	No
INTERBUS	3 / 6 no. twisted pairs, various	Yes
PROFIBUS DP	IEC 61158 Type A (22AWG?)	No

Link segment/PHY - Considerations

Link segment insertion loss

- Insertion loss derived from link segment components insertion losses and insertion loss deviation of link segment.
  - Cable IL
  - Connecting hardware IL
  - Link segment ILD

- Related characteristics to consider.
  - Gauge
  - Shield
  - Temperature dependencies



Cable insertion loss – 20 deg C

- **Link Segment Insertion Loss Specifications**
  - **Automotive**
  - **Industrial Automation**

AWG	Diameter(in)	Diameter(mm)	dB/m at 50 MHz solid	dB/m at 100 MHz solid	dB/m at 500 MHz solid	dB/m at 50 MHz stranded	dB/m at 100 MHz stranded	dB/m at 500 MHz stranded
14	0.064085	1.627754	0.05	0.07	0.16	0.06	0.08	0.19
15	0.057069	1.449551	0.05	0.08	0.18	0.06	0.09	0.21
16	0.050821	1.290858	0.06	0.08	0.20	0.07	0.10	0.24
17	0.045257	1.149538	0.07	0.10	0.23	0.08	0.11	0.27
18	0.040303	1.023689	0.07	0.11	0.25	0.09	0.13	0.30
19	0.035890	0.911618	0.08	0.12	0.28	0.10	0.14	0.34
20	0.031961	0.811816	0.09	0.14	0.32	0.11	0.16	0.38
21	0.028462	0.722941	0.11	0.15	0.36	0.13	0.18	0.43
22	0.025346	0.643795	0.12	0.17	0.40	0.14	0.20	0.48
23	0.022571	0.573314	0.13	0.19	0.45	0.16	0.23	0.54
24	0.020100	0.510549	0.15	0.21	0.51	0.18	0.26	0.61
25	0.017900	0.454655	0.17	0.24	0.57	0.20	0.29	0.68
26	0.015940	0.404881	0.19	0.27	0.64	0.23	0.33	0.77
27	0.014195	0.360555	0.21	0.30	0.72	0.25	0.37	0.86
28	0.012641	0.321083	0.24	0.34	0.81	0.29	0.41	0.97
29	0.011257	0.285931	0.27	0.38	0.91	0.32	0.46	1.09
30	0.010025	0.254628	0.30	0.43	1.02	0.36	0.52	1.22
31	0.008927	0.226752	0.34	0.48	1.14	0.41	0.58	1.37
32	0.007950	0.201928	0.38	0.54	1.28	0.46	0.65	1.54

*Reference IL =1.82*SQRT(f)+0.0091*f+0.25/SQRT(f)*
**commercially available specified to 500 MHz*
***~12% increase per gauge*
****20% increase for stranded*

Automotive operating environment

Lifetime Requirements and Testing of ECUs

Active Operation: Typical Temperature-Load Distribution (ambient)

$T_{I,ECU}$ = ECU inner air temperature	Typ. load (Passenger Car)	
	Vehicle body, bulkhead, extension close to the engine	
-40°C..10° C	6.0 %	480 h
10°C...45° C	20.0 %	1600 h
45°C...60° C	33.0 %	2640 h
60°C...70° C	18.0 %	1440 h
70°C...80° C	9.0 %	720 h
...85° C	3.0 %	240 h
...90° C	2.0 %	160 h
...95° C	1.7 %	136 h
...100° C	1.5 %	120 h
...105° C	1.4 %	112 h
...110° C	1.3 %	104 h
...115° C	1.2 %	96 h
...120° C	1.0 %	80 h
...125° C	0.9 %	72 h
Total	100%	8000 h

Automotive Electronics

4 DGS-EC/EHM3-Mrt | 6/25/2012 |

BOSCH

http://grouper.ieee.org/groups/802/3/RTPGE/public/july12/hoganmuller_01a_0712.pdf

Cable temperature correction

ANSI/TIA/EIA-568-C.2 – Annex G

G.2 Insertion loss

Equation (G-1) defines the insertion loss dependence on temperature:

$$IL_{20} = \frac{IL_T}{1+\delta_1(T-20)+\delta_2(T-40)}$$

where:

IL_T = Measured insertion loss at temperature T

IL_{20} = Insertion loss corrected to 20℃

T = Measured temperature in ℃

The correction factors, δ_1 and δ_2, are shown in table G.1.

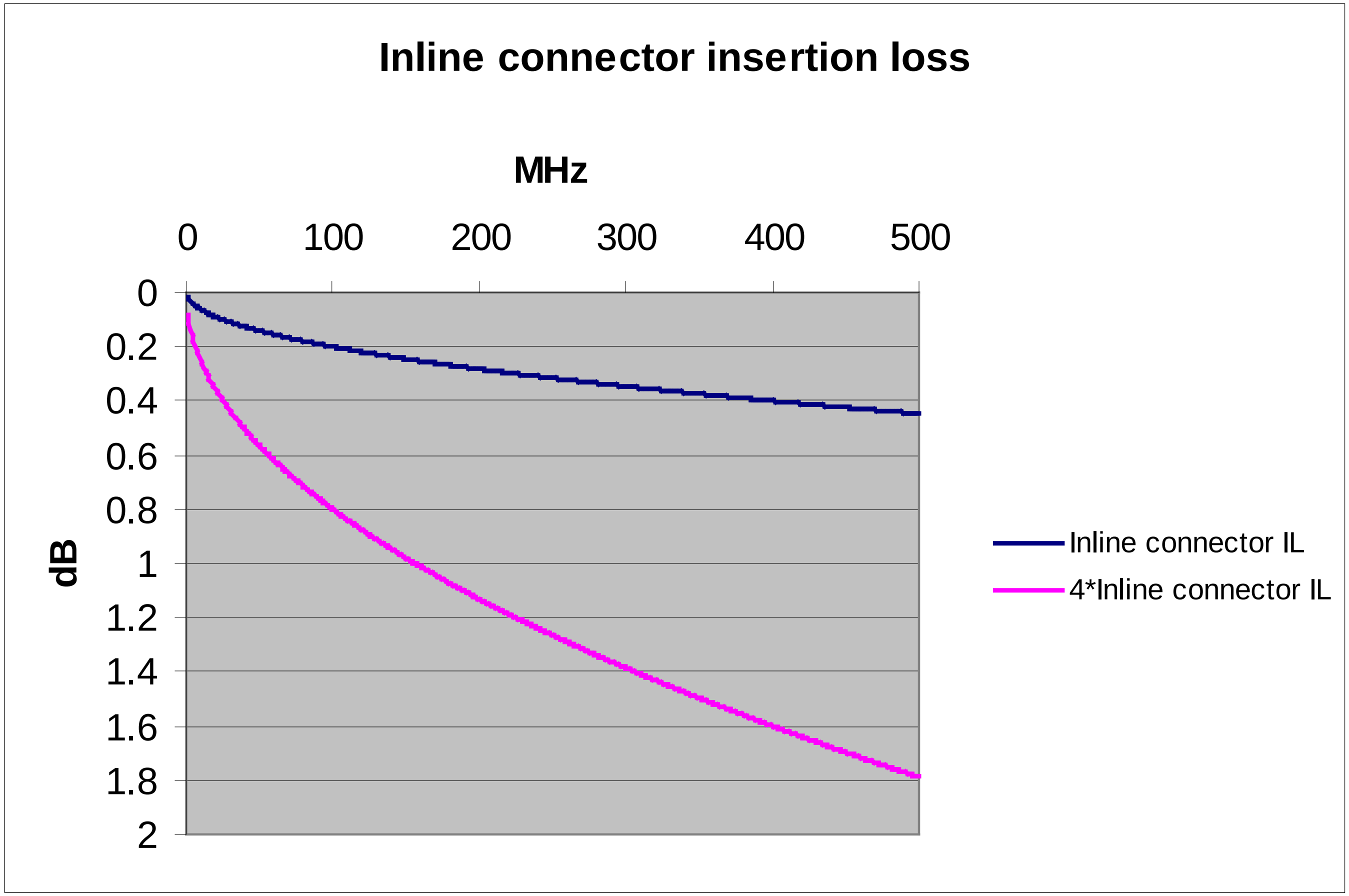
Table G.1 – Maximum horizontal cable length de-rating factor for different temperatures

	Temperature (° C)	δ_1	δ_2
UTP	$20 \le T \le 40$ $40 < T \le 60$	0.004 0.004	0 0.00248
F/UTP	$20 \le T \le 60$	0.002	0

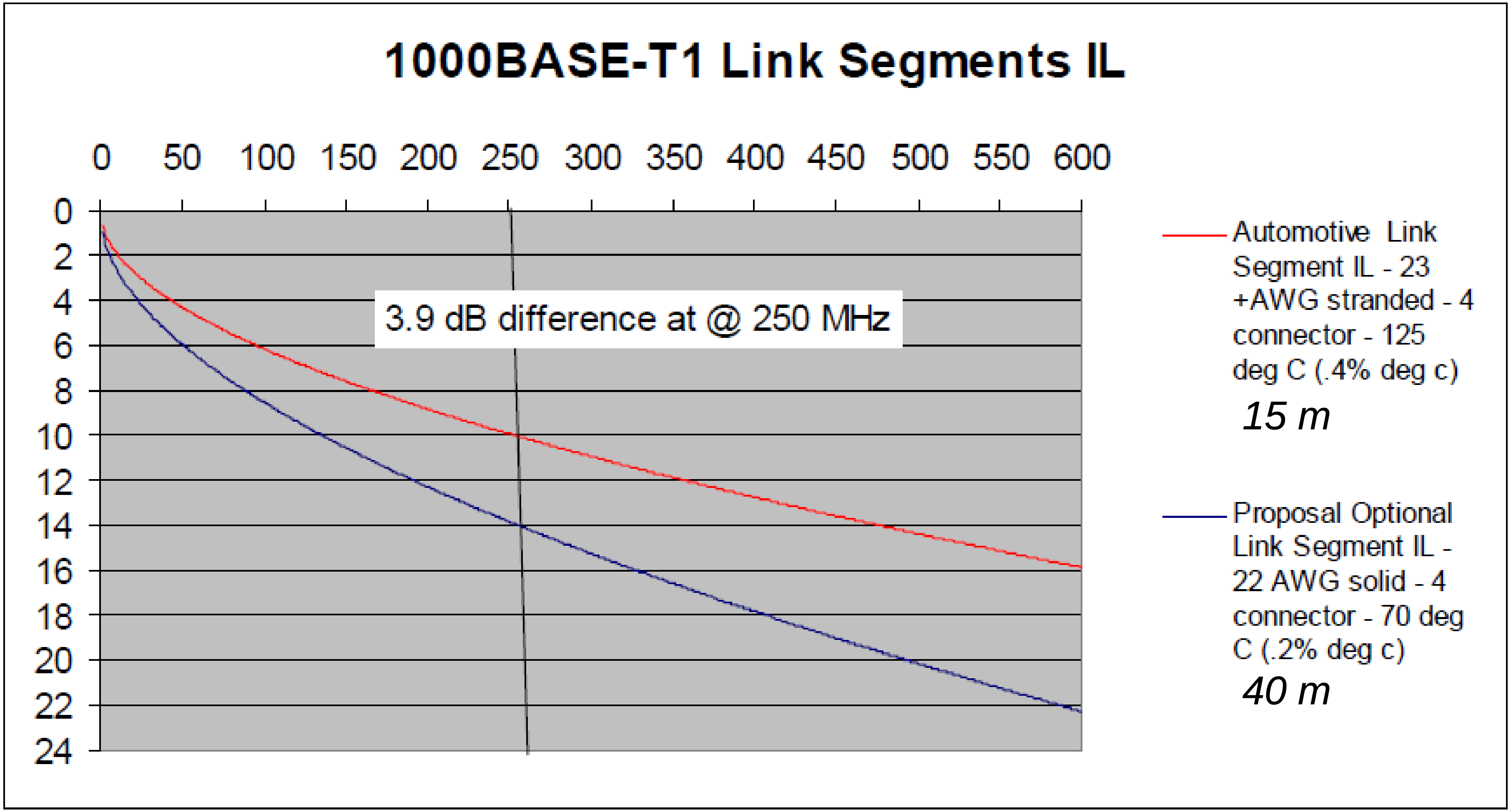
T	sigma 1	sigma 2	Loss factor
20	0.004	0	1
25	0.004	0	1.02
30	0.004	0	1.04
35	0.004	0	1.06
40	0.004	0	1.08
45	0.004	0.00248	1.1124
50	0.004	0.00248	1.1448
55	0.004	0.00248	1.1772
60	0.004	0.00248	1.2096
65	0.004	0.00248	1.242
70	0.004	0.00248	1.2744
75	0.004	0.00248	1.3068
80	0.004	0.00248	1.3392
85	0.004	0.00248	1.3716
90	0.004	0.00248	1.404
95	0.004	0.00248	1.4364
100	0.004	0.00248	1.4688
105	0.004	0.00248	1.5012
110	0.004	0.00248	1.5336
115	0.004	0.00248	1.566
120	0.004	0.00248	1.5984
125	0.004	0.00248	1.6308

Inline connector insertion loss assumed 802.3bp

- Inline connector IL(f) = x*sqrt(f)
- x=0.02*sqrt(f)

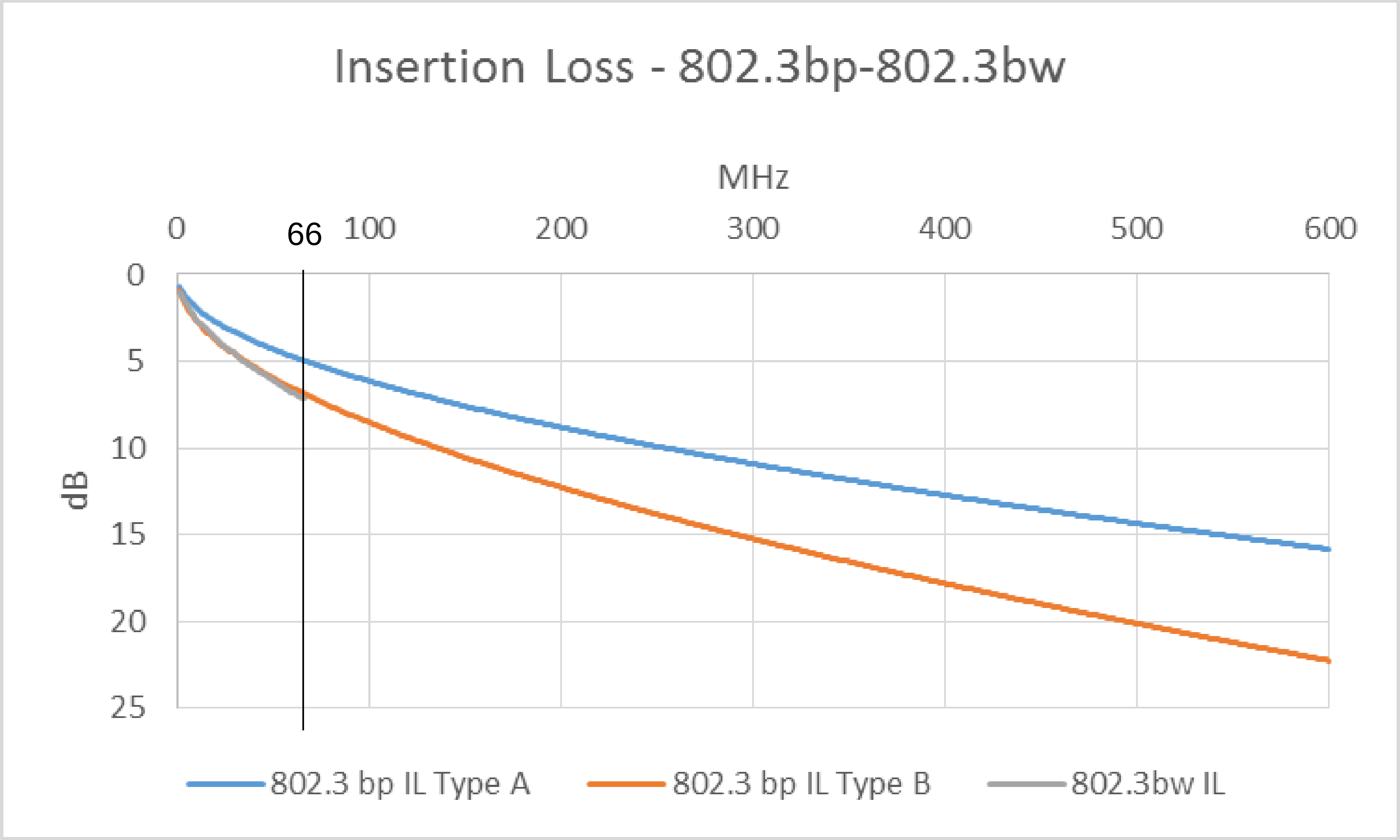


Link segment insertion loss comparison

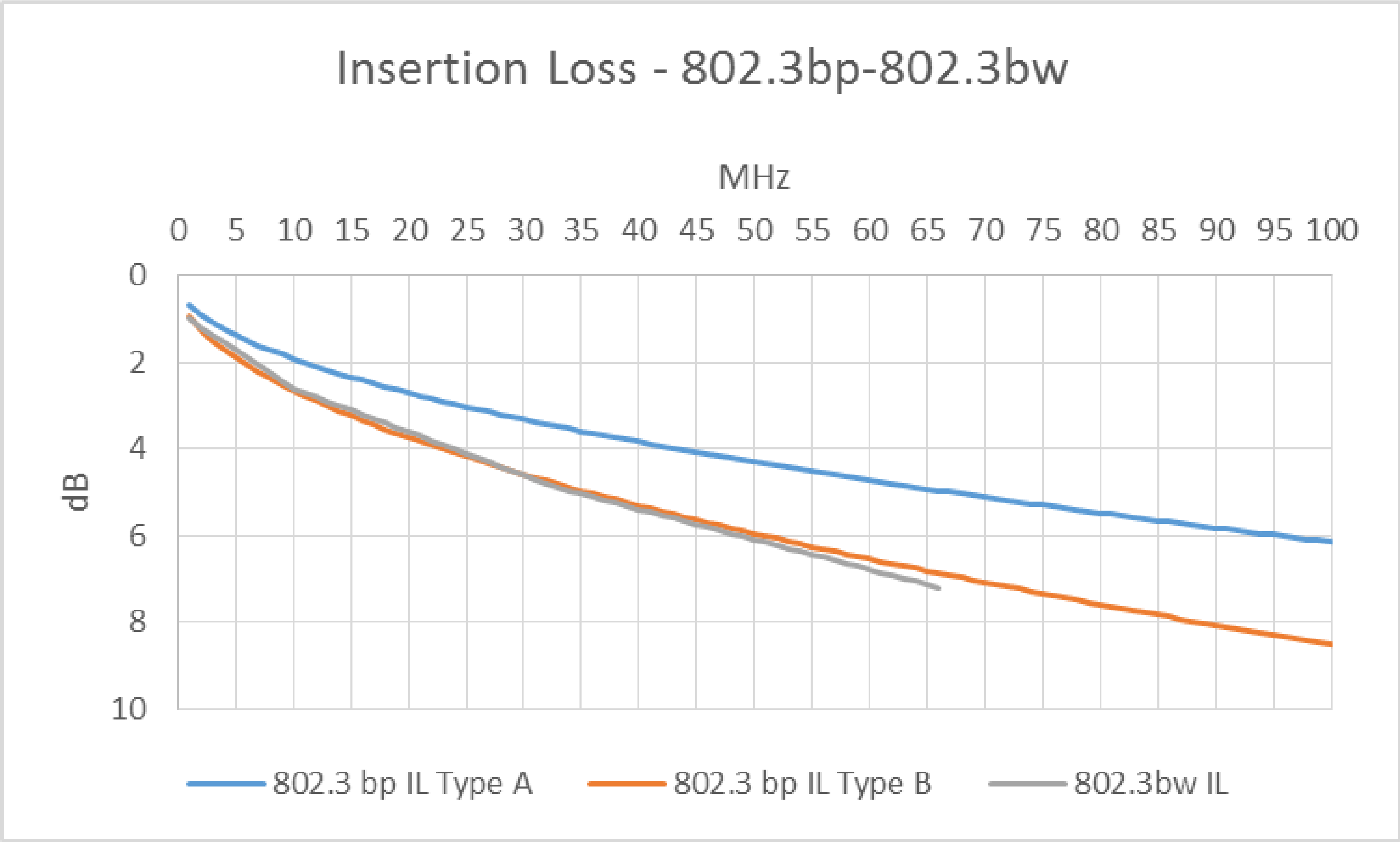


Source: http://www.ieee802.org/3/bp/public/jul14/diminico_3bp_01b_0714.pdf

Link segment insertion loss comparison



Link segment insertion loss comparison



Summary

- Initiate discussion(s) on 10 Mb/s Single Twisted Pair Ethernet Link Segment Insertion Loss Specifications
  - Automotive
  - Industrial Automation

- Insertion loss length dependencies limit achievable link length distances (reach objectives)

- Link segment characteristics enables considerations for PHY (e.g., signaling)

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