SAE INTERNATIONAL

SURFACE VEHICLE STANDARD

J3117™/2 NOV2021

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1000BASE-T1 Un-Shielded and Shielded Balanced Single Twisted Pair Ethernet Cable

RATIONALE

This is a new standard for un-shielded and shielded balanced single twisted pair jacketed data cable intended for use in surface vehicle cables for 1000BASE-T1 ethernet PHY (1 Gb/s) applications.

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1. SCOPE

This standard covers un-shielded (JUTP) and shielded (STP) balanced single twisted pair jacketed data cable intended for use in surface vehicle cables for 1 Gb/s ethernet applications. The tests in this standard are intended to qualify cables for normal operation in an automotive environment while maintaining the necessary electrical properties for reliable data transmission.

1.1 Application

The 1 Gb/s cable is used for 1000BASE-T1 ethernet PHY applications.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1678 Low Voltage Ultra-Thin Wall Primary Cable

SAE J3117 Un-Shielded Balanced Single Twisted Pair Ethernet Cable

SAE EA-1128 Wire Color Charts

2.1.2 ISO Publications

Copies of these documents are available online at http://webstore.ansi.org/.

ISO 6722-1 Road Vehicles - 60 V and 600 V Single Core Cables - Test Methods, Dimensions and Requirements.

ISO 14572 Road Vehicles - Round, Sheathed, 60 V and 600 V Screened and Unscreened Single- or Multi-Core Cables - Test Methods and Requirements for Basic- and High-Performance Cables

ISO 19642-1 Road Vehicles - Automotive Cables - Part 1: Vocabulary and Design Guidelines

ISO 19642-2 Road Vehicles - Automotive Cables - Part 2: Test Methods

ISO 19642-3 Road Vehicles - Automotive Cables - Part 3: Dimensions and Requirements for 30 Vac or 60 Vdc Single Core Copper Conductor Cables

ISO 19642-7 Road Vehicles - Automotive Cables - Part 7: Dimensions and Requirements for 30 Vac or 60 Vdc, Round, Sheathed, Screened or Unscreened Multi or Single Core Copper Conductor Cables

2.1.3 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE Std 802.3 Clause 96 - Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) Sublayer and Baseband Medium, Type 100BASE-T1

IEEE Std 802.3 Clause 97 - Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) Sublayer, and Baseband Medium, Type 1000BASE-T1

2.1.4 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B5423 Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

ASTM B5374 Standard Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

2.1.5 Other Publications

Available from OPEN ALLIANCE website: www.opensig.org.

OPEN Alliance Channel and Components Requirements for 1000BASE-T1 Link Segment Type A (STP) version 2.0 (2020)

OPEN Alliance Channel and Components Requirements for 1000BASE-T1 Link Segment Type A (UTP) version 2.0 (2018)

3. DEFINITIONS

For the purposes of this document, the following terms and definitions apply.

3.1 CROSSTALK

A measurement of the unwanted signal transmitted from one aggressor circuit or channel of a transmission system to the victim circuit or channel (for two or more channels in the same bundle).

3.2 EMC CLASSIFICATION (CLASS 1 AND CLASS 2)

The amount of additional EMC margin, i.e., the degree of shielding and coupling attenuation, may depend on the specific implementation in the vehicle. Two electromagnetic environment classes are defined to provide most flexibility for choosing suitable components. Class 1 relies on lower mode conversion allowing simpler shielding while Class 2 requires full shielding. The coupling and screening attenuation limits for Class 1 are more relaxed compared to Class 2. The selection of the appropriate limit class depends on the specific application in the vehicle and is not subject of this specification.

3.3 IMPEDANCE (Z)

The total opposition to alternating current by an electric circuit, equal to the square root of the sum of the squares of the resistance and reactance of the circuit and usually expressed in ohms, denoted as Z.

3.4 INSERTION LOSS (ATTENUATION)

The ratio of transmitted power to received power measured at the end of the cable expressed in decibels (dB). This is the s-parameter defined as Sdd_{21} or Sdd_{12}.

3.5 JUTP

Jacketed (sheathed) un-shielded twisted pair.

3.6 LONGITUDINAL CONVERSION LOSS (LCL)

A ratio, expressed in decibels (dB), of the differential mode (DM) signal applied between the wires in a pair and the resulting common mode (CM) noise signal reflected at the same end. This is the s-parameter defined as Sdc_{11} and Sdc_{22}.

3.7 LONGITUDINAL CONVERSION TRANSMISSION LOSS (LCTL)

A ratio, expressed in decibels (dB), of the differential mode (DM) signal applied between the wires in a pair and the resulting common mode (CM) noise signal transmitted from one end to the other end.

This is the s-parameter defined as Sdc_{21} and Sdc_{12}.

3.8 LOW VOLTAGE (LOW TENSION)

Usually considered to be ≤60 VDC (25 VAC).

3.9 MINIMUM WALL (THICKNESS)

The lowest allowable insulation thickness at any point.

3.10 NOMINAL

A suitable approximate value used to designate or identify a component.

3.11 PHY

Abbreviation for the physical layer device. A PHY connects a link layer device to a physical medium such as a copper cable or optical fiber. A PHY chip (PHYceiver) is commonly found on ethernet devices. Its purpose is to provide analog signal physical access to the link.

3.12 RETURN LOSS

A ratio, expressed in decibels (dB), of the power of the outgoing signal to the power of the reflected or returned signal.

This is the s-parameter defined as Sdd_{11} and Sdd_{22}.

3.13 S-PARAMETER

Table 1

Single Channel Characteristics (Port 1, 2)		
RL	S_{dd11}, S_{dd22}	Return loss (differential mode)
IL	S_{dd21}	Insertion loss (differential mode)
LCL	S_{dc11}, S_{dc22}	Longitudinal conversion loss
LCTL	S_{dc12}, S_{dc21}	Longitudinal conversion transmission loss

3.14 STP

Shielded twisted pair.

3.15 TEMPERATURE CLASS RATING (TCR)

A temperature class designation based on the long term heat aging (3000 hours) test.

3.16 WCC

Whole communication channel is the complete electrical wire connection between two ECUs.

4. GENERAL

4.1 Classification

4.1.1 Temperature Classes

Four cable classes have been defined in Table 2 to respond to the various temperatures encountered on vehicles.

Table 2 - Temperature class

Class	Operating Temperature	Equivalent to Temperature Class	Typical Usage
A	-40 °C to +85 °C	T1	Interior wiring harness (IP, body, headliner, doors, liftgate)
B	-40 °C to +100 °C	T2	Engine bay, forward lamp
C	-40 °C to +125 °C	T3	Engine
D	-40 °C to +150 °C	T4	On engine, behind engine

4.2 General Test Conditions

Test samples shall be preconditioned for at least 16 hours at a room temperature of 23 °C ± 3 °C. Unless otherwise specified, all tests shall be conducted at this same temperature. All samples shall pass. In the case where the test result is based on an average, the average shall meet the requirement.

4.3 Ovens

Unless otherwise specified, when an oven is required, it shall be a hot air oven in accordance with ASTM D5374 and ASTM D5423. The air contained in the oven shall be completely changed at least eight times, but not more than 20 times per hour at the specified temperature.

4.4 Tolerances

Unless otherwise specified, all values are considered to be approximate.

4.5 Representative Conductor Sizes for Testing

When a test is required, all combinations of conductor size, wall thickness, and insulation formulation shall meet the appropriate requirements.

5. GENERAL SPECIFICATIONS

The finished cable shall meet the requirements for all tests specified in Table 3 for each cable type.

Table 3 - General specifications

Clause	Description	Initial tests	Periodic tests
5	GENERAL SPECIFICATIONS		
5.1	Cable Types		
5.1.1	Single Core ISO Cable	X(1)	
5.1.2	Single Core SAE Cable	X(1)	
5.1.3	Outer Jacket (Sheath)	X(2)	
5.2	Construction	X	X
5.3	Cable Breaking Strength	X	X
5.4	Ovality of Jacket (Sheath)	X(2)	X(2)
5.5	Electrical Performance		
5.5.2	Characteristic Impedance	X	X(3)
5.5.3	Insertion Loss (IL)	X	X(3)
5.5.4	Return Loss (RL)	X	X(3)
5.5.5	Conversion Loss (LCL and LCTL)	X	X(3)
5.5.6	Coupling and Screening Attenuation	X	X(3)

NOTES:
(1) Test the individual core cable to either the ISO 6722-1, ISO 19642-3, or SAE J1678.
(2) The usage of this test is established by agreement between customer and supplier.
(3) For periodic testing, perform the electrical performance (5.5) testing at room temperature only. Periodic testing is normally performed once every 3 years or per customer requirements.

5.1 Cable Types

Each insulated conductor (JUTP, STP) shall meet the test and performance requirements of the following sections in ISO 6722-1 (2011), ISO 19642-3 (2019), or SAE J1678. See Figure 1 for typical constructions of JUTP and STP cables. (Performance requirements include electrical, mechanical, and environmental requirements.)

5.1.1 Single Core ISO Cable

The cable shall meet ISO 6722-1 (2011), Sections 5.5 to 5.22, or the current ISO 19642-3 Sections 5.3, 5.4, and 5.5.

5.1.2 Single Core SAE Cable

The cable shall meet the current SAE J1678, Sections 6.3 to 6.16.

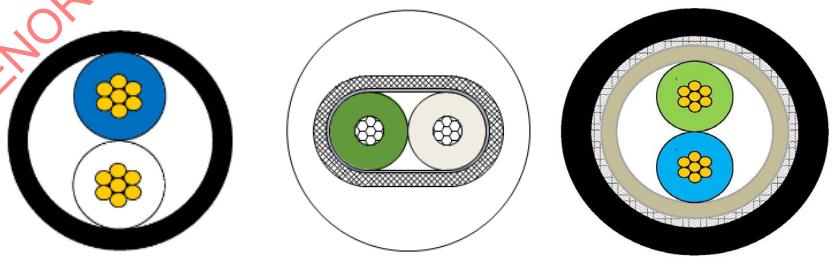

Figure 1 - Un-shielded and shielded balanced single twisted pair (1 Gb/s) ethernet cable

5.1.3 Outer Jacket (Sheath)

For the outer jacket (sheath) of the JUTP and STP cable, the test and requirements for the finished cable shall be according to ISO 14572 (2011), Sections 5.5 and 5.7 to 5.21, or the current ISO 19642-7 (2019) Section 6.

5.2 Construction

The construction of the ethernet cable (JUTP, STP) will be according to Table 4.

Table 4 - Ethernet cable construction

					JUTP (Jacketed Unshielded Twisted Pair)			STP (Jacketed Shielded Twisted Pair)		
SAE J1678 Size (SAE No.)	ISO 6722-1/ 19642-3 Size (mm^2)	Conductor Material	Number of Strands	Conductor OD (Max) (mm)	Insulated Conductor OD[1]		Jacket OD	Insulated Conductor OD		Jacket OD
					Min (mm)	Max (mm)	Min-Max (mm)	Min (mm)	Max (mm)	Min-Max (mm)
26	0.13	Cu Alloy, Bare Cu, Tin Plated Copper	7	0.55	0.77	0.95	3.00-3.50	0.90	1.26	3.60-4.30
24	0.22	Bare Cu, Tin Plated Copper	7	0.70	1.05	1.20	3.00-3.50	1.10	1.55	4.00-5.60
22	0.35	Bare Cu, Tin Plated Copper	7	0.90	1.21	1.50	3.60-4.50	1.40	2.00	4.50-6.50
20	0.5	Bare Cu, Tin Plated Copper	19	1.10	1.55	1.78	4.20-5.00	1.90	2.60	6.00-8.00

NOTES:
(1) Insulated conductor for OD (for each core of the twisted pair).

5.3 Cable Breaking Strength

Test method: Refer to ISO 19642-3, Section 5.3.3.

Requirement: Breaking strength shall be ≥90 N.

5.4 Ovality of Jacket (Sheath)

The usage of this test is established by agreement between customer and supplier.

5.4.1 Test

For a jacketed (sheathed) cable, the test and requirements shall be according to ISO 14572 (2011), Section 5.2.

5.4.2 Requirement

The maximum allowable “out of round” shall be 20%.

5.5 Electrical Performance

Testing of the cable’s electrical performance shall be follows:

- Initial test of “as received” sample, 23 °C and -40 °C.
- Test after long term 3000 hours heat aging at TCR.

The electrical performance tests can be done on a single sample or different samples from the same lot of twisted pair cable. The oven or test chamber does not have to meet the air exchange of 4.3.

5.5.1 Test Temperature

Test at room termperature and -40 °C as per Table 5.

Table 5 - Test temperature for initial "as received" sample

Initial Test on "As Received" Sample	Test at Temperature After Conditioned 16 Hours	Test at Temperature After Conditioned 1 to 3 Hours	Test at Temperature After Conditioned 4 Hours
Impedance	23 °C	TCR	-40 °C
IL	23 °C	TCR	-40 °C
RL	23 °C	TCR	-40 °C
LCL and LCTL	23 °C	TCR	-40 °C

Test at TCR for long term heat aging, 3000 hours, as per Table 6. See Figure 2 for test setup and fixture.

Table 6 - Test temperature 3000 hours heat aging

Test	Sample Length	Test Temperature and Measurement
Impedance, IL, RL, LCL, LCTL	10 m	At TCR: Final measurement within one hour after 3000 hours aging.
		At 23 °C: After the 3000 hour heat aging and measurement, ramp down to 23 °C and conditioned for a minimum of 4 hours, then take measurement.

Figure 2 - Test setup for heat aging test at TCR (example shown below)

The measurement (reference) plane must be maintain outside of the test chamber.

Effective dielectric constant of spacer material: ≤1.4.

Note 1:

- Sample length: 10 m, the cable shall be routed around the drum with minimum separation of 30 mm.
- Drum dimension examples: 300 mm diameter wide x 500 mm height; 460 mm diameter x 435 mm height.
- Position of drum: Lay it vertical or horizontal.
- For unshielded cable (JUTP), the drum is required and needs a ground plane (10.0 mm ± 1.0 mm).
- For shielded cable (STP), a conductive drum (ground plane) is not required.
- Length of cable (60 to 100 mm) exiting out of the temperature chamber.

Note 2: To address the unreferenced portion of cable during the temperature testing (referencing the hanging cable in the above figure).

- Option 1: Due to a missing or an undefined relation to ground resulting in measuring results that would not be equal to those conducted on a proper ground plane. Measure with a turned off oven (in the oven as shown), then conduct the same measurement on the ground plane. Then you can create a reference/relation model that later is applied onto the results reached in the oven to "correct" the impact of the missing ground.

- Option 2: Other methods such as de-embedding or port extensions can be used.

5.5.2 Characteristic Impedance

5.5.2.1 Test

Refer to OPEN Alliance "Channel and Component Requirements for 1000BASE-T1 Link Segment Type A (STP)."

5.5.2.2 Vector Network Analyzer (VNA) Calibration Accuracy.

Measurements to be perform using linear sweep.

5.5.2.3 Requirement

The characteristic impedance shall be within the limit of Table 7 with 500 pico-seconds rise time (1 to 600 MHz).

Table 7 - Characteristic impedance

Parameter	Symbol	Minimum (ohm)	Nominal (ohm)	Maximum (ohm)
Impedance	Z	90	100	110

5.5.3 Insertion Loss (IL)

Test per OPEN Alliance "Channel and Component Requirements for 10000BASE-T1 Link Segment Type A (STP) (Version 2.0)" specification.

For testing at various temperatures (-40 °C, RT, and TCR), the sample shall be conditioned at each temperature 30 minutes prior to testing.

5.5.3.1 Requirement

The requirements for IL are shown in the equations below and in Figure 3 (10 m/15m) and Figure 4 (40 m).

The limit line covers -40 °C to the upper limit of temperature class rating (at TCR).

Generally, a cable designed to meet the 15 m requirements is not expected to meet the 40 m requirements.

5.5.3.1.1 For 10 m and 15 m Max Channel Length

$$\mathrm{IL} \leq \frac{1}{\mathrm{L}}\left(0.0023\mathrm{f} + 0.5907\sqrt{\mathrm{f}} + \frac{0.0639}{\sqrt{\mathrm{f}}} - 6 * 0.01\sqrt{\mathrm{f}}\right) \mathrm{dB}/\mathrm{m}$$

$$\mathrm{L} = 10 \text{ for } 10 \text{ m requirement}$$

$$\mathrm{L} = 15 \text{ for } 15\mathrm{m} \text{ requirement}$$

$$\mathrm{f} \text{ is in MHz: } 1 \leq \mathrm{f} \leq 600$$

NOTE: The insertion loss formula is for "cable only." The $(-6 * 0.01\sqrt{\mathrm{f}})$ term is accounting for the six connectors: two end connectors and four inlines. For specific application calculation/simulation, L can be substituted with the intended cable length.

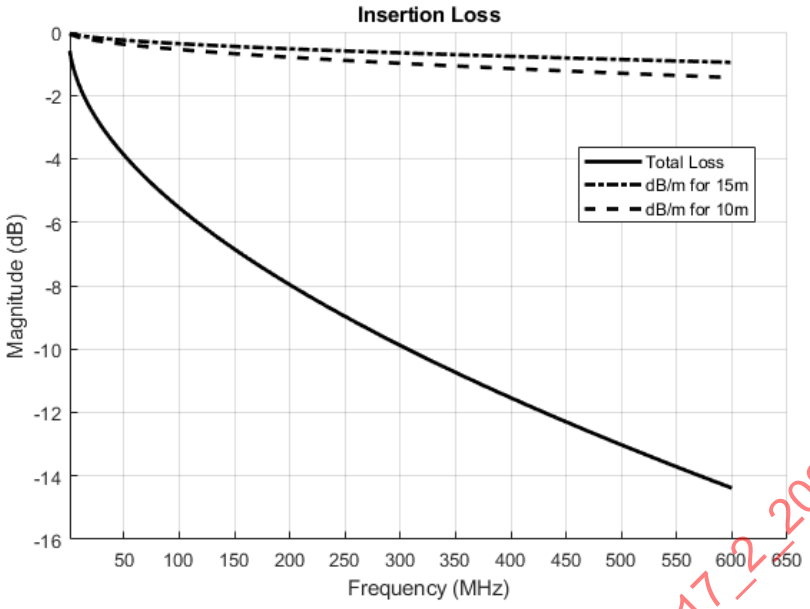

Figure 3 - Insertion loss requirement (10 m/15m)

5.5.3.1.2 For 40 m Max Channel Length

$$IL \leq \frac{1}{L}\left(0.0040f + 0.7131\sqrt{f} + 0.08\sqrt{f} + 0.018\sqrt{f} + \frac{0.1100}{\sqrt{f}} - 6 * 0.01\sqrt{f}\right) \text{ dB/m}$$

$$L = 40 \text{ for 40 m requirement}$$

$$f \text{ is in MHz: } 1 \leq f \leq 600$$

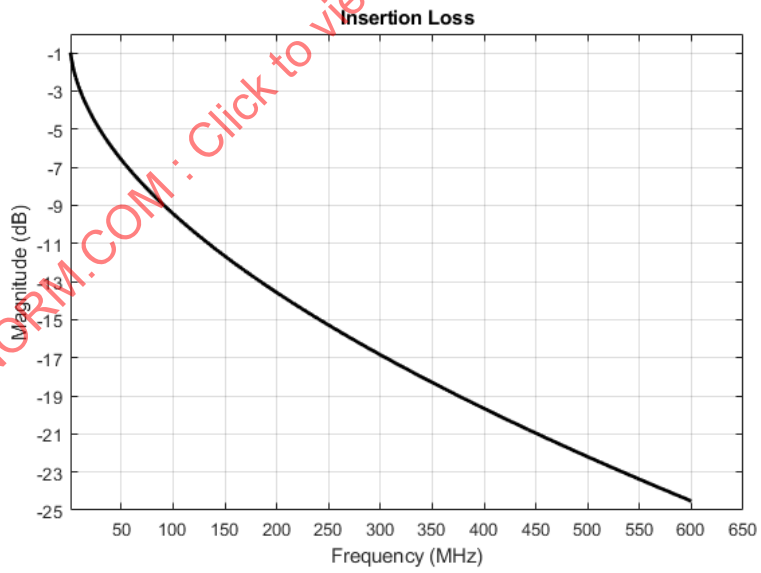

Figure 4 - Insertion loss requirement (40 m)

NOTE: For actual application requiring length up to 40 m, consider the calculation of insertion loss (IL) to include a section for the high temp (i.e., 125 °C) zone and a section for the lower temp zone (i.e., 85 °C).

If the cable IL meets the 40 m at TCR, then it can be used up to its TCR up to 40 m.

5.5.4 Return Loss (RL)

5.5.4.1 Requirement

The requirement for 10 m, 15 m, and 40 m cable lengths are shown in the following equation and Figure 5.

The limit line covers -40 °C to the upper limit of temperature class rating (@atTCR).

$$\mathrm{RL} \leq (-20 \mid 1 \leq \mathrm{f} \leq 600)\mathrm{dB}, \mathrm{f\ is\ in\ MHz}$$

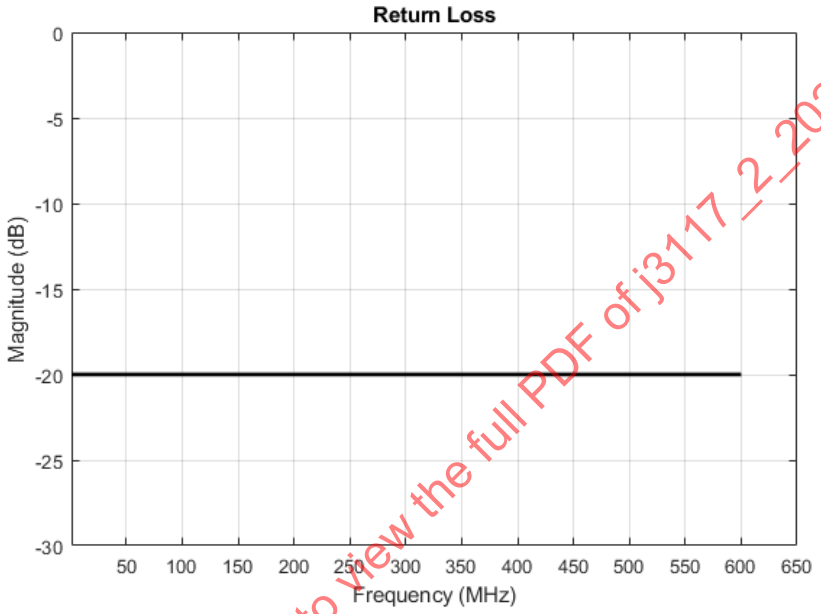

Figure 5 - Return loss requirement

NOTE: RL is not impacted by the longer length as much as with IL. Based on test data, a shorter cable (i.e., 1 m cable with four inlines will have the most impact on the return loss, as compare to 3 m or 5 m cable).

When testing “cable and connectors” together at elevated temperature, there are some changes in the return loss.

For multiple inline connectors, the better the matching connector’s impedance, the better over performance (less impact on the return loss).

5.5.5 Conversion Loss (LCL and LCTL)

5.5.5.1 JUTP Single Pair

See Figure 6. This applies to unshielded twisted pair (JUTP).

The limit line covers -40 °C to the upper limit of temperature class rating (at TCR) for a single pair cable.

$$\begin{pmatrix} -55 & \mid\ 10 \leq \mathrm{f} < 80 \\ -77 + 11.5 \log_{10} \mathrm{f} & \mid 80 \leq \mathrm{f} < 600 \end{pmatrix} \mathrm{dB}$$

$$\mathrm{f\ is\ in\ MHz}: 1 \leq \mathrm{f} \leq 600$$

$$\text{Port reference impedances: } 100\Omega(\mathrm{DM}), 200\Omega(\mathrm{CM})$$

NOTE: The 200 Ω common mode impedance based on specific test method setup.

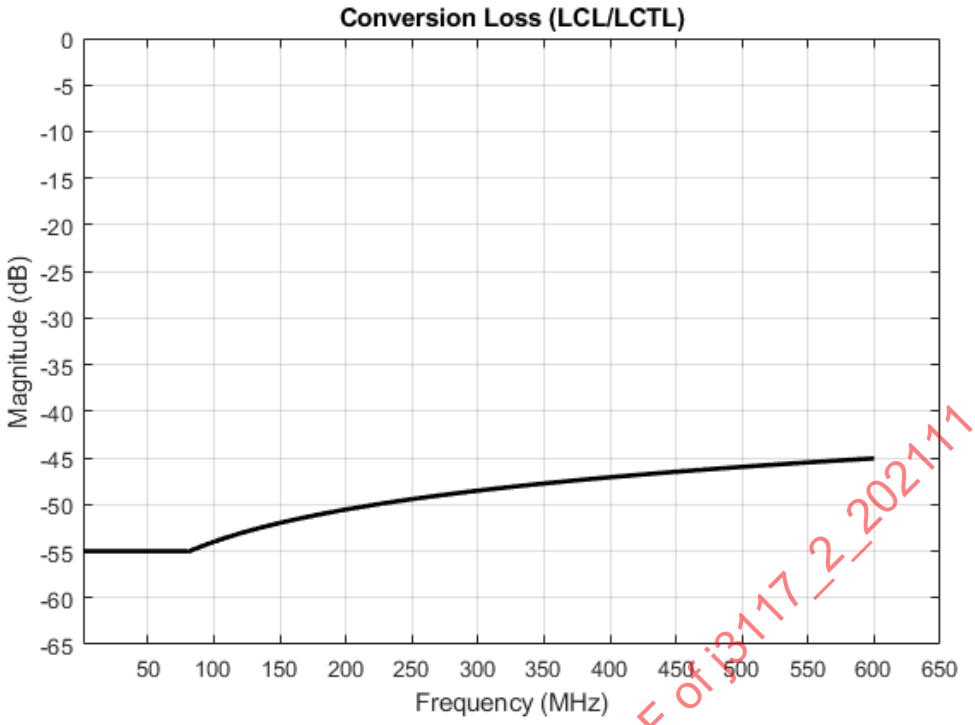

Figure 6 - JUTP conversion loss (LCL and LCTL) requirement

5.5.5.2 STP Single Pair (10/15/40 m)

See Table 8 and Figure 7 for requirements of single shielded twisted pair (STP) 10/15/40 m.

Table 8 - LCL and LCTL test parameter and requirements

Test Parameter	Symbol	Requirement
LCL	S_{dc11}, S_{dc22} class 1	$\leq \begin{pmatrix} -50 & 10 \leq f < 50 \\ -81.5 + 18.53\log_{10}(f) & 50 < f < 600 \end{pmatrix}$ dB f is in MHz: $10 \leq f \leq 600$
	S_{dc11}, S_{dc22} class 2	No requirement
LCTL	S_{dc21}, S_{dc12} class 1	$\leq \begin{pmatrix} -46 & 10 \leq f < 50 \\ -71.2 + 14.83\log_{10}(f) & 50 < f < 600 \end{pmatrix}$ dB f is in MHz: $10 \leq f \leq 600$
	S_{dc21}, S_{dc12} class 2	No requirement