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PCI-SIG ENGINEERING CHANGE NOTICE

TITLE:	OCuLink Cable Spec ECN
DATE:	March 23, 2018
AFFECTED DOCUMENT:	OCuLink 1.0
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Part I:

1. Summary of the Functional Changes

The IL/ fitted IL requirements have been clarified. The language of this portion of the spec has been reworked to eliminate confusion and provide uniformity in the subsections included in the following document.

2. Benefits as a Result of the Changes

The signal integrity requirements necessary for OCuLink compliance have been clarified. The method for calculating fitted IL has been simplified. The equations for limit lines have been redefined to report values as losses (positive values).

3. Assessment of the Impact

This section of the spec has been made easier to follow and is therefore less likely to misinterpret.

4. Analysis of the Hardware Implications

Connectors and cables must adhere to the fully specified signal integrity requirements described in the following text.

5. Analysis of the Software Implications

None, this change does not affect software.

Part II: Changes are reflected in Sections 7.3 through 7.3.6 (begins on the next page).

7.3 Mated Cable Assembly Electrical Specifications

The OCuLink cable assembly contains insulated conductors terminated in a connector at each end for use as a l~~L~~ink segment between host boards. This cable assembly is primarily intended as a point-to-point interface between host boards using controlled impedance cables. All mated cable assembly measurements are to be made between TP1 and TP4 with CCB test fixtures, which includes a connector mated to either end of the cable assembly. CCB test fixtures are to be removed before comparing measured performance against the specifications listed in this section. It is recommended measurements be de-embedded using a TRL calibration (see Section 7.4 for more information on de-embedding).~~.~~ All requirements are to be met when analyzed in an 85 Ω reference frame.

~~-~~Th~~es~~e mated cable assembly ~~S~~specifications are based upon twin axial cable characteristics. Table 7-1 provides a summary of the cable assembly characteristics and references addressing each parameter.~~ Reported values are at 4 GHz.~~ Limits apply to 2.5 GT/s, 5.0 GT/s, and 8.0 GT/s data rates and are written in terms of baud frequency. Baud frequencies are 2.5 GHz, 5 GHz, and 8 GHz for the 2.5 GT/s, 5.0 GT/s, and 8.0 GT/s data rates, respectively. Note that plots show loss (positive values).

Table 7-1. Mated Cable Assembly Differential Characteristics Summary

Description	Reference	Value	Unit
Maximum differential insertion loss	7.3.2	~~15~~Equation 7-1	dB
~~Minimum insertion loss~~	~~7.3.2~~	~~0~~	~~dB~~
Minimum differential return loss	7.3.3	Equation ~~(~~7-2~~5)~~	dB
Minimum ~~D~~differential to common-mode return loss	7.3.4	Equation ~~(~~7-3~~6)~~	dB
Minimum d~~D~~ifferential to common-mode conversion loss minus i~~I~~nsertion l~~L~~oss	7.3.5	Equation ~~(~~7-4~~7)~~	dB
Minimum c~~C~~ommon-mode ~~to common-mode~~ return loss	7.3.6	Equation ~~(~~7-5~~8)~~	dB
Minimum MDNEXT loss	7.3.7	Equation ~~(~~7-8~~9)~~	dB
Minimum MDFEXT loss	7.3.7	Equation ~~(~~7-9~~10)~~	dB
~~OCuLink~~ Maximum t~~T~~otal ~~C~~cable a~~A~~ssembly, Lane-to-Lane ~~S~~skew (Sc)	7.3.8	0.9~~6~~	ns ~~MAX~~

7.3.1. Characteristic Impedance and Reference Impedance

The nominal differential characteristic impedance of the cable assembly is 85 Ω. The differential reference impedance for cable assembly ~~Specifications~~ must be 85 Ω.

7.3.2. Pinout for x4 Fixed Internal Connector (root)Mated Cable Assembly Differential Insertion Loss

The differential insertion loss of each pair of a mated OCuLink cable assembly, in dB, must be less than the maximum limit defined in Equation 7-1, as illustrated in Figure 7-5.

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

Equation 7-1 $$ILCable(f) = 2 + 5.5\sqrt{f} + 0.5\,f$$ for 0.05 GHz ≤ f ≤ f_b GHz

Where:

f is the frequency, in GHz

f_b is the baud frequency, in GHz

ILCable(f) is the maximum mated cable assembly insertion loss, in dB

The fitted cable assembly insertion loss *IL Cable fitted* (*f*), as a function of frequency *f*, is defined in Equation (7-1).

Equation (7-1)

$$\boldsymbol{ILCablefitted(f) = a_1\sqrt{f} + a_2 f + a_4 f^2}$$

Where:

f is the frequency in GHz

ILCable(f) is the fitted cable assembly insertion loss, in dB

Given the cable assembly insertion loss measured between TP1 and TP4 is at *N* uniformly-spaced frequencies f_n spanning the frequency range 50 MHz to 12000 MHz with a maximum frequency spacing of 10 MHz, the coefficients of the fitted insertion loss are determined using Equation (7-2) and Equation (7-3).

MHz.

Define the frequency matrix, *F*, as shown in Equation (7-2).

Equation (7-2)

$$F = \begin{bmatrix} \sqrt{f_1} & f_1 & f_1^2 \\ \sqrt{f_2} & f_2 & f_2^2 \\ \cdots & \cdots & \cdots \\ \sqrt{f_N} & f_N & f_N^2 \end{bmatrix}$$

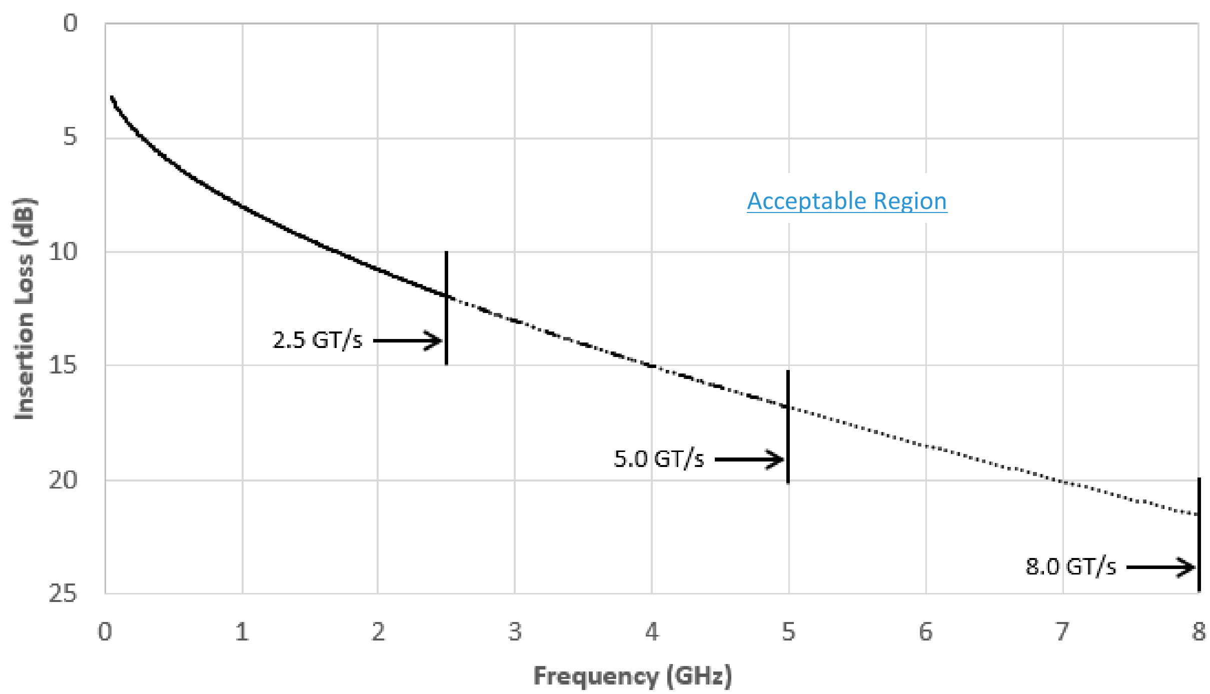
Note: The polynomial coefficients a_1, a_2 and a_4 are determined using Equation (7-3). In Equation (7-3), T denotes the matrix transpose operator and IL is a column vector of the measured insertion loss value, IL_n at each frequency, f_n.

Equation (7-3)

$$\begin{bmatrix} a_1 \\ a_2 \\ a_4 \end{bmatrix} = (F^T F)^{-1} F^T IL$$

~~Examples of maximum and minimum fitted insertion loss are illustrated in Figure 7-5. The coefficients for the maximum loss curve are: a1 = 6.9, a2 = 0.6, and a4 = 0.05.~~

~~The coefficients for the minimum loss curve are: a1 = 0.5, a2 = 0.18, and a4 = 0.~~



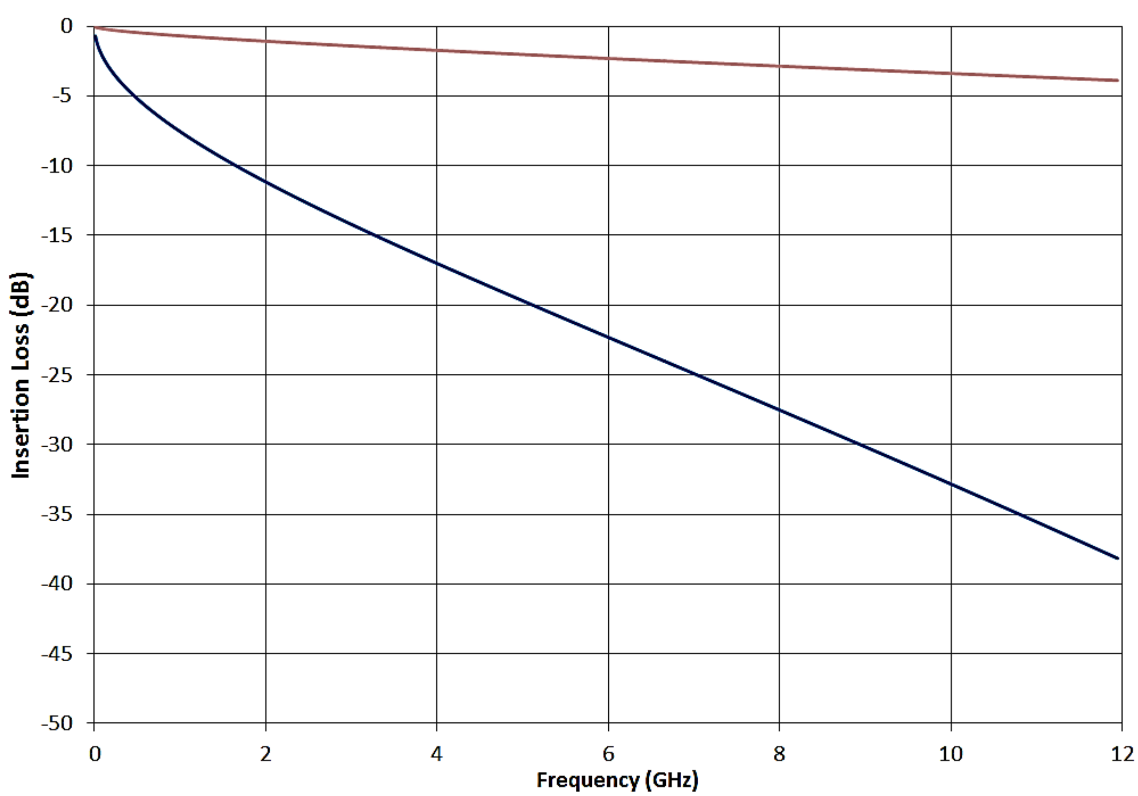


Figure 7-~~5~~5: ~~Example~~ Maximum Mated Cable Assembly Insertion Loss

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1 This insertion loss limit is intended to accommodate cables up to 2 m long (using 34 awg).

7.3.3. Mated Cable Assembly Differential Return Loss

The differential return loss of each pair of the mated OCuLink cable assembly, in dB, must be greater than the minimum limit defined in~~meet the values determined using~~ Equation ~~(~~7-2~~4)~~, as illustrated in Figure 7-6.

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

Equation 7-2

$$RLCable(f)=\begin{cases} 10\ \text{dB} & \text{for } 0.05\ \text{GHz} \le f \le 2\ \text{GHz} \\ (12-f)\ \text{dB} & \text{for } 2\ \text{GHz} < f \le f_b\ \text{GHz} \end{cases}$$

Where:

f	is the frequency, in GHz
f_b	is the baud frequency, in GHz
RLCable(f)	is the maximum mated cable assembly return loss, in dB

~~Equation (7-4)~~

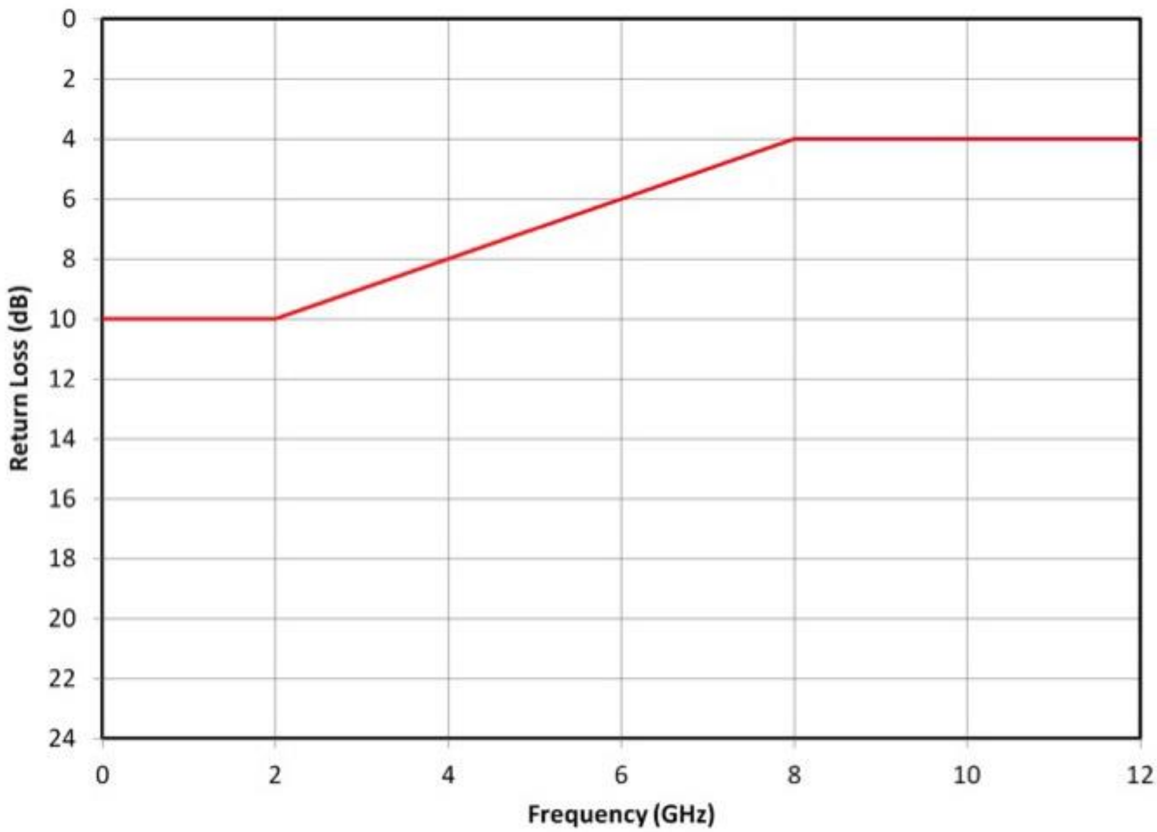
RLCable(f) =

~~-~~10 dB for 0.05 ≤~~<~~ f ≤~~<~~ 2 GHz

(12-f~~-12~~) dB for 2 < f ≤~~<~~ 8 GHz

~~-~~4 dB for 8 < f ~~<~~≤ 12 GHz

Acceptable Region



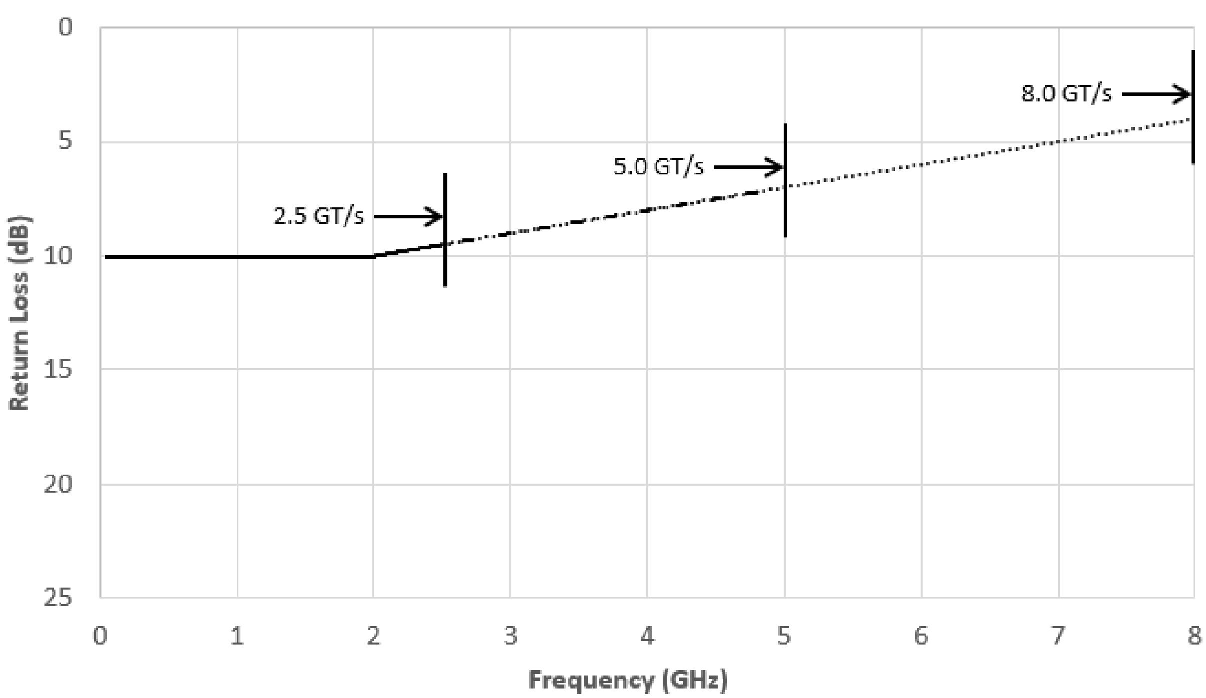


Figure 7Error! No text of specified style in document.-16: Minimum Mated Cable Assembly Return Loss

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7.3.4. Mated Cable Assembly Differential to C~~c~~ommon-mode R~~r~~eturn ~~l~~Loss

The differential to common-mode return loss of the mated OCuLink cable assembly, in dB, ~~of the cable assembly~~ must be greater than the minimum defined in~~meet~~ Equation ~~(~~7-3~~5)~~, ~~as~~which is illustrated in Figure 7-7.

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

Equation 7-3

$$\mathrm{DCMCCable(f)} = 20 - \left(\frac{2}{3}\right) f \qquad \text{for } 0.05\ \text{GHz} \le f \le f_b\ \text{GHz}$$

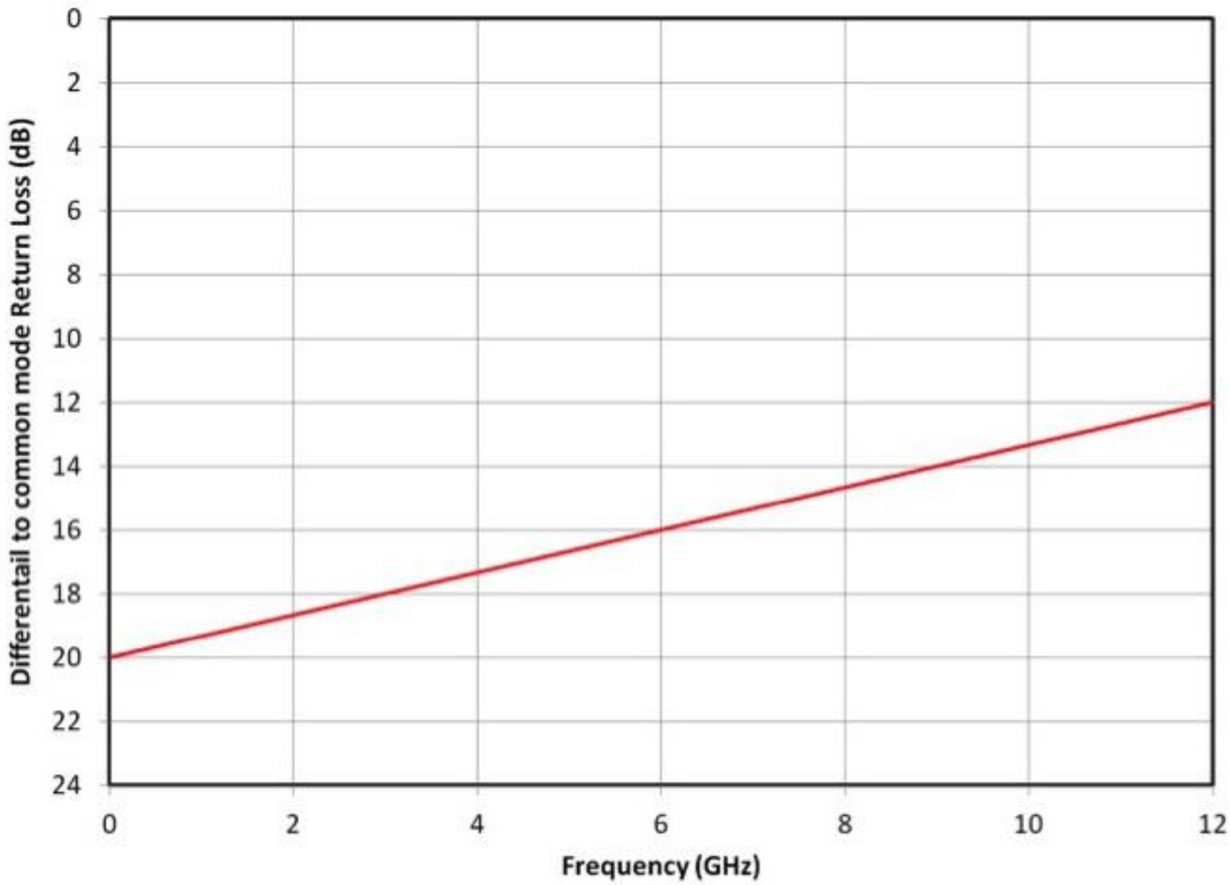
Where:

f	is the frequency, in GHz
f_b	is the baud frequency, in GHz
DCMCRL(f)	is the minimum mated cable assembly differential to common-mode return loss, in dB

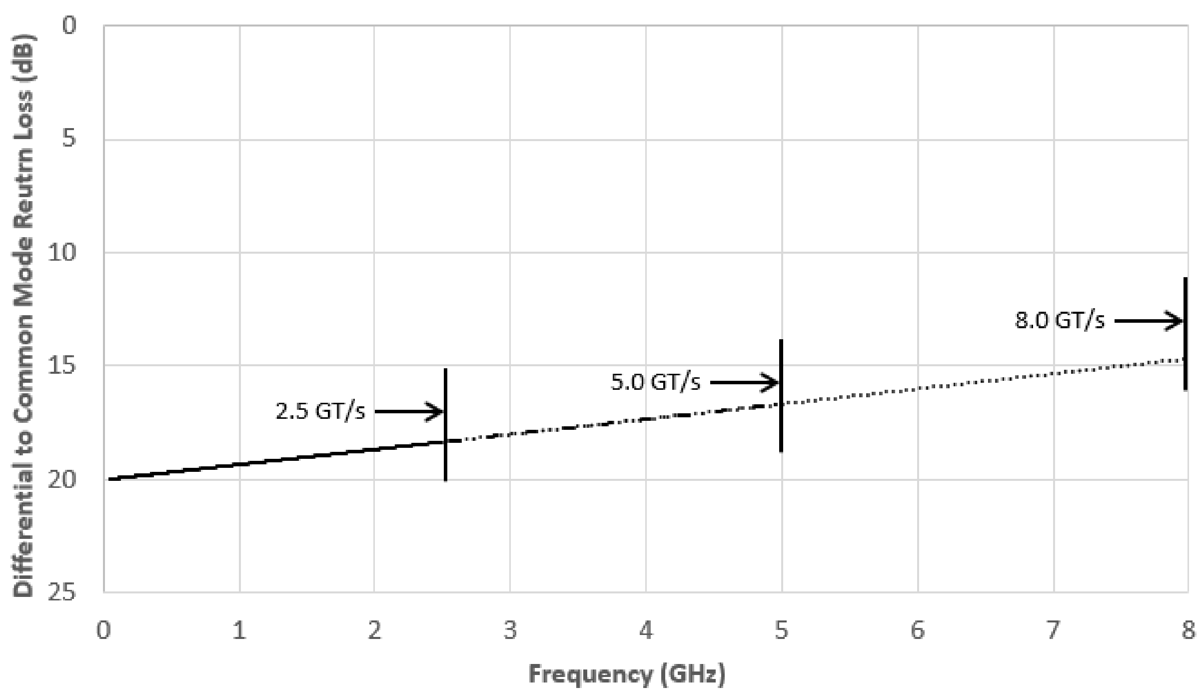
~~Equation (7-5)~~

DifftoCMRLCable(f) = 20-(2/3)f ~~– 20~~ dB for 0.05 GHz ≤ ~~<~~ f ≤ ~~<~~12 GHz

Acceptable Region


Differentail to common mode Return Loss (dB)
0
2
4
6
8
10
12
14
16
18
20
22
24
0
2
4
6
8
10
12
Frequency (GHz)

1


Differential to Common Mode Reutrn Loss (dB)
0
5
10
15
20
25
0
1
2
3
4
5
6
7
8
Frequency (GHz)
2.5 GT/s
5.0 GT/s
8.0 GT/s

2

Figure ~~Error! No text of specified style in document.~~7-~~2~~7: Minimum Mated Cable Assembly Differential to Common-mode ~~Cable Assembly~~ Return Loss

7.3.5. Mated Cable Assembly Differential to Common-mode Conversion Loss minus Insertion Loss

The difference between the mated OCuLink c~~c~~able assembly differential to common-mode conversion loss and the cable assembly insertion loss, in dB, must ~~meet~~ be greater than the minimum limit defined in Equation ~~(~~7-4~~6)~~.

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

Equation 7-4

$$\mathrm{DCMC\text{-}ILCable}(f) = 10\ \mathrm{dB} \qquad \text{for } 0.05\ \mathrm{GHz} \le f \le f_b\ \mathrm{GHz}$$

Where:

f	is the frequency, in GHz
f_b	is the baud frequency, in GHz
DCMC(f)	is the mated cable assembly differential to common-monde insertion loss, in dB
ILCable(f)	is the mated cable assembly differential insertion loss, in dB

~~Equation (7-6)~~

$$\mathrm{DifftoCMConv\text{-}ILCable}(f) = -10\ \mathrm{dB\ for\ } 0.05 \le f \le 12\ \mathrm{GHz}$$

7.3.6. Mated ~~Common-mode to~~ Cable Assembly Common-mode Return Loss

The ~~common-mode to~~ common-mode return loss of the mated OCuLink cable assembly, in dB~~, of the cable assembly~~ must ~~meet~~ be greater than the minimum limit defined in Equation ~~(~~7-~~7)~~5.

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

Equation 7-5

$$\mathrm{CMRLCable}(f) = 2\ \mathrm{dB} \qquad \text{for } 0.05\ \mathrm{GHz} \le f \le f_b\ \mathrm{GHz}$$

Where:

f	is the frequency, in GHz
f_b	is the baud frequency, in GHz
CMRLCable(f)	is the minimum mated cable assembly common-mode return loss, in dB

~~Equation (7-7)~~

CMRLCable(f) = ~~-~~2 dB for 0.05 ≤~~<~~ f ≤~~<~~ 12 GHz

7.3.7. Mated ~~Connector/Cable~~Cable Assembly Crosstalk

Crosstalk between differential pairs influences the data signals and any subsequent loss and jitter budgets. All system board and cable assembly designs must properly account for any crosstalk that may exist among the various pairs of differential signals. Crosstalk is due to coupling through a channel, ~~may be~~ either at the near-end (NEXT) or at the far-end (FEXT). The total contribution from all aggressors on a particular victim is captured by the multi-disturber or powersum crosstalk.

The NEXT loss that couples within a channel is from Lanes that transmit data in the opposite direction as the victim Lane. Therefore, MDNEXT loss on a receive Lane must be summed across contributions from the four transmit Lanes at the near end of the mated cable assembly, yielding four aggressors total for a four-Lane interface. Similarly, the FEXT loss that couples within a channel is from the Lanes that transmit data in the same direction as the victim Lane. Therefore, MDFEXT loss on a receive Lane must be summed across contributions from the three remaining receive Lanes at the far end of the mated cable assembly, yielding three aggressors total for a four-Lane interface.

Equation 7-6 provides the calculation for MDNEXT loss; Equation 7-7 provides the calculation for MDFEXT loss.~~Each component potentially, has impact on a design and must be planned for accordingly. The equation for NEXT is shown in Equation 7-8; the equation for FEXT is shown in Equation 7-9.~~

~~Crosstalk between differential pairs influences and impacts the data signals and any subsequent loss and jitter budgets. Note that all eye diagrams must account for any and all crosstalk present, in order to limit crosstalk impacts and implications. All system boards interfacing with a cable assembly must also properly account for crosstalk. The system board must also account for potential crosstalk that occurs on the printed circuit board, as well as within the connector itself.~~

Equation 7-6

$$\mathrm{MDNEXT(f)} = -10\log_{10}\sum_{i=0}^{i=3} 10^{-NL_i(f)/10} \quad \text{for } 0.05\text{ GHz} \le f \le f_b \text{ GHz}$$

Where:

f	is the frequency, in GHz
f_b	is the baud frequency, in GHz
MDNEXT(f)	is the multi-disturber near-end crosstalk loss at frequency f
$NL_i(f)$	is the NEXT loss at frequency f of victim-aggressor combination i, in dB
i	is the victim-aggressor pair (0 to 3)

~~Equation (7-8)~~

$$\mathbf{MDNEXT\_loss}(f) = -10\log_{10}\sum_{i=0}^{i=3}10^{-NLi(f)/10} \quad \text{for } 0.05 \text{ GHz} \le f \le 12 \text{ GHz}$$

~~Where:~~

~~MDNEXT_loss(*f*) is the MDNEXT loss at frequency *f*~~

~~*$NL_i(f)$* is the NEXT loss at frequency *f* of pair combination *i*, in dB~~

~~*F* is the frequency, in GHz~~

~~i is the 0 to 3 (pair-to-pair combination)~~

~~The MDNEXT loss between a receive Lane and all transmit Lanes (e.g., closest in proximity) must meet the limits specified by Equation (7-9).~~

Equation 7-7

$$\mathrm{MDFEXT(f)} = -10\log_{10}\sum_{i=0}^{i=2}10^{-FL_i(f)/10} \qquad \text{for } 0.05 \text{ GHz} \le f \le f_b \text{ GHz}$$

Where:

f	is the frequency, in GHz
f_b	is the baud frequency, in GHz
MDFEXT(f)	is the multi-disturber far-end crosstalk loss at frequency f
$FL_i(f)$	is the FEXT loss at frequency f of victim-aggressor combination i, in dB
i	is the victim-aggressor pair (0 to 2)

The MDNEXT loss and MDFEXT loss summed on each receive Lane of a mated OCuLink cable must be greater than the limits defined in Equations 7-8 and 7-9 respectively. These limits are illustrated in Figure 7-8.

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

Equation 7-8 $$\mathrm{MDNEXTCable(f)} = 31.5 - 12.5\log_{10}\left(\frac{f}{4}\right)\ \mathrm{dB}$$ for $0.05\ \mathrm{GHz} \le f \le f_b$ GHz

Where:

f is the frequency, in GHz

f_b is the baud frequency, in GHz

MDNEXTCable is the minimum mated cable assembly MDNEXT loss, in dB

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:~~Equation 7-9)~~

~~MDNEXT_loss(f) ≥ 31.5 – 12.5 x log(f / 4) dB 0.05 GHz ≤ f ≤ 12 GHz~~

~~Where:~~

~~f is the frequency, in GHz~~

~~Equation (7-10)~~

$$\mathbf{MDFEXT\_loss}(f) = -10\log_{10}\sum_{i=0}^{i=2} 10^{-NLi(f)/10}$$ ~~for 0.05 GHz ≤ f ≤ 12 GHz~~

~~Where:~~

~~MDFEXT_loss(f) is the Multi-Disturber Far End Cross Talk loss at frequency f~~

~~$NL_i(f)$ is the FEXT loss at frequency f of pair combination i, in dB~~

~~F is the frequency, in GHz~~

~~i is the 0 to 2 (pair-to-pair combination)~~

~~The MDFEXT loss between a receive Lane at the far end and with the noise source (Transmitters) at the near end must meet the limits specified by Equation (7-11).~~

Equation 7-9 $$\mathrm{MDFEXTCable(f)} = 31 - 15\log_{10}\left(\frac{f}{4}\right)\ \mathrm{dB}$$ for $0.05\ \mathrm{GHz} \le f \le f_b$ GHz

Where:

f is the frequency, in GHz

f_b is the baud frequency, in GHz

MDFEXTCable is the minimum mated cable assembly MDFEXT loss, in dB

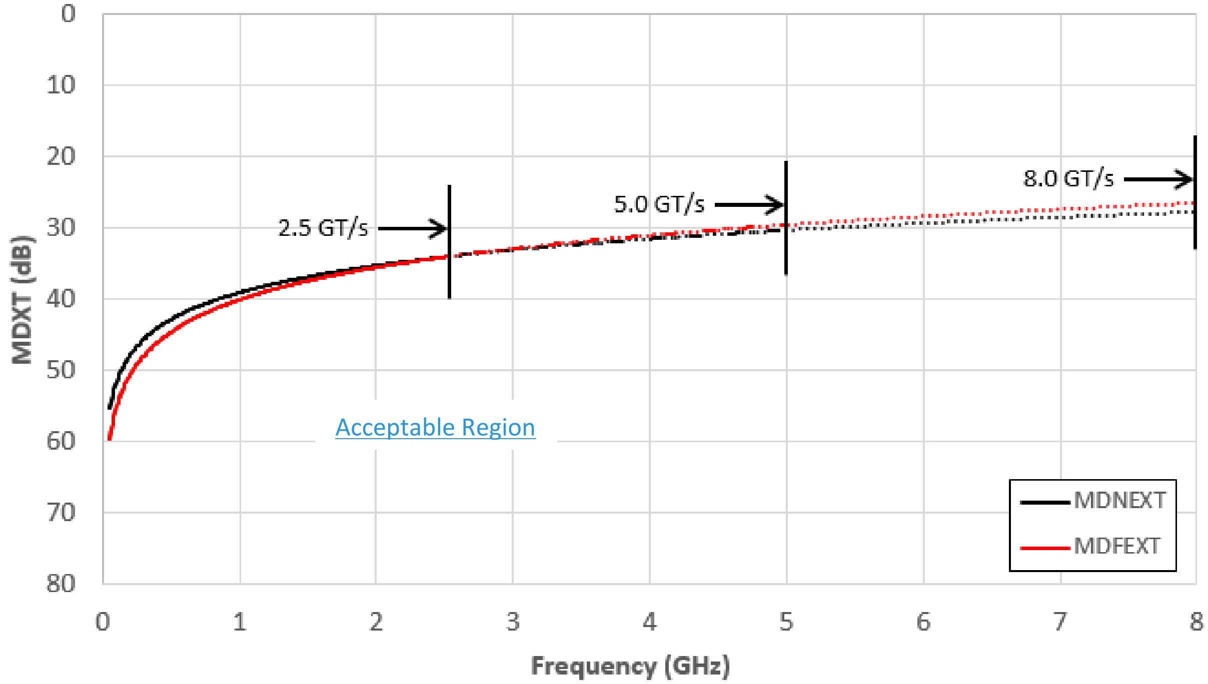


Figure 7-8: Minimum Mated Cable Assembly MDNEXT Loss and MDFEXT Loss

~~Equation (7-11)~~

~~MDFEXT_loss(f) ≥ 31 – 15 x log(f / 4) dB 0.05 GHz ≤ f ≤ 12 GHz~~

~~Where:~~

~~f is the frequency, in GHz~~

7.3.8. ~~Connector/Cable~~ Lane-to-Lane Skew

The ~~skew~~ time delay across a cable assembly at any point is measured using zero crossings of differential voltage of the compliance pattern, while simultaneously transmitting on all physical L~~L~~anes. ~~-~~The compliance pattern is defined in the *PCI Express Base Specification*. The skew for a mated cable assembly is quantified as the difference between the longest and shortest time delays measured for a given assembly. The maximum skew permitted for 2.5 GT/s, 5.0 GT/s, and 8.0 GT/s OCuLink cable assemblies in 0.9ns.

7.3.9. Within-Lane Skew

Maximum within-Lane skew is not specified in this specification in the time domain. Within-Lane skew is instead controlled in the frequency domain by means of the restrictions on differential-to-common mode return loss and differential-to-common mode conversion loss minus insertion loss.~~.~~