Modal ERL Proposed Comment Overview
Addressing D3.0 modal ERL Comments i-46, i-239, i-153 to i-165

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Modal ERL Computation

Reference in mellitz_3dj_01b_2603.pdf

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Includes:

- Update for modal s-parameter references in 178A.1.2
- Proposal for a new section 178A.3 for Modal Effective Return Loss computation

Modal ERL Documentation Example

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Table 176D–2—Summary of host output specifications at TP1a

Parameter	Reference	Value	Units
Signaling rate (range)	176D.8.1	106.25 ± 50 ppm	GBd
Differential peak-to-peak voltage (max) Output disabled Output enabled	176D.8.2	 0.03 1	 V V
DC common-mode voltage (range)	176D.8.2	0.2 to 1	V
AC common-mode peak-to-peak voltage (max) Low-frequency, VCM_{LF} Full-band, VCM_{FB}	176D.8.2	 0.032 0.085	 V V
Effective return loss, ERL (min)	176D.8.3	7.3	dB
~~Common-mode to common-mode return loss, $RLcc$ (min)~~	~~176D.8.4~~	~~Equation (179–15)~~	~~dB~~
~~Common-mode to differential-mode return loss, $RLdc$ (min)~~	~~176D.8.4~~	~~Equation (179–16)~~	~~dB~~

Common-mode to common-mode return loss	176D.8.4	Table 176D-8a	
Common-mode to differential-mode return loss	176D.8.4	Table 176D-8a	

- Rename modal return loss entries to point to table 178D-8a referenced in 178D.8.4

Modify 176D.8.4 and add Table 176D-8a

The common-mode to common-mode return loss specification is satisfied by either meeting the requirement of Equation (179-15) or having ERL_{CC} value higher than the specification in Table 176D-8a.

The common-mode to differential-mode return loss specification is satisfied by either meeting the requirement of Equation (179-16) or having ERL_{DC} value higher than the specification in Table 176D-8a.

The differential-mode to common-mode return loss specification is satisfied by either meeting the requirement of Equation (179-23) or having ERL_{CD} value higher than the specification in Table 176D-8a.

Table 176D-8a shows which equations and modal ERL specifications are required for the return loss specifications. ERL_{CC}, ERL_{DC}, and ERL_{CD} are computed using the procedure in annex 178A.3 with the values in Table 176D–7 and Table 176D–8, with differential reference impedance equal to 92.5 Ω, common mode impedance of 23.125 Ω, and with *Tfx* equal to twice the test fixture delay. *Tfx* is provided by the test fixture provider. For host input and output, the test fixture delay is defined as the propagation delay between the coaxial connector on the test fixture and the host-facing connection, excluding the mating interface discontinuity. For module input and output, the test fixture delay is defined as the propagation delay between the coaxial connector on the test fixture and the first discontinuity of the AUI-C2M connector.

Table 176D-8a

Specification	RL mask equation	RL mask figure	Modal ERL type	Modal ERL minimum
Common-mode to common-mode	Equation (179–15)	Figure 179–4	ERL_{CC}	2 dB
Common-mode to differential-mode	Equation (179–16)	Figure 179–5	ERL_{DC}	17 dB
differential-mode to common-mode	Equation (179–23)	Figure 179–7	ERL_{CD}	17 dB

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	tx			rx			channel tx or rx		
	RLcc	Rldc	Rlcd	RLcc	Rldc	Rlcd	RLcc	Rldc	Rlcd
178.9.2 Transmitter characteristics									
178.9.3 Receiver characteristics									
178.10 Channel characteristics									table 178-13
179.9.4 Transmitter characteristics	table 179-7	table 179-7							
179.9.5 Receiver characteristics						table 179-11			
179.11 Cable assembly characteristics							table 179-16		table 179-16
176C.6.3 Transmitter characteristics									
176C.6.4 Receiver characteristics									
176C.7 Channel characteristics									table 176C-8
176D.6.4 Host output characteristics	table 176D-2	table 176D-2							
176D.6.5 Module output characteristics	table 176D-3	table 176D-3							
176D.6.6 Host input characteristics						table 176D-4			
176D.6.7 Module input characteristics						table 176D-5			
179B.4.5 MTF DC								p. 914	
179B.4.3 MTF CC							p. 913		

Adopt the data in the proposal mellitz_3dj_03a_2603 slide 3 with exceptions below

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section	tx			rx			channel tx or rx		
	ERLcc	ERLdc	ERLcd	ERLcc	ERLdc	ERLcd	ERLcc	ERLdc	ERLcd
178.9.2 Transmitter characteristics									
178.9.3 Receiver characteristics									
178.10 Channel characteristics									17 dB
179.9.4 Transmitter characteristics (CR Host)	2 dB	17 dB							
179.9.5 Receiver characteristics (CR Host)						17 dB			
179.11 Cable assembly characteristics							2 dB		17 dB
176C.6.3 Transmitter characteristics									
176C.6.4 Receiver characteristics									
176C.7 Channel characteristics									17 dB
176D.6.4 Host output characteristics	2 dB	17 dB							
176D.6.5 Module output characteristics	2 dB	17 dB							
176D.6.6 Host input characteristics						17 dB			
176D.6.7 Module input characteristics						17 dB			
179B.4.5 MTF DC								17 dB	
179B.4.3 MTF CC							2 dB		

Summary

Ref to straw poll #13 in
https://www.ieee802.org/3/dj/public/26_03/motions_3dj_2603.pdf

Straw Poll #13

I would support using modal ERL per mellitz_3dj_03a_2603 slides 2-3 for D3.1

Y: 45, N 13, A 28

Apply modal ERL as described in this presentation which corrects and clarifies mellitz_3dj_03a_2603, slides 2 and 3.

Thank You!

Backup – Modal ERL Document

SEE MELLITZ_3DJ_02_ADHOC_260421.PDF FOR A CLEARER VIEW

Document: IEEE802.3dj Modal ERL Proposal

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178A.1.2 Channel

Each signal path and modal parameter of the channel is measured according to the guidance given in 178A.1.3 to obtain the differential-mode scattering matrix $S(f)$, common-mode scattering matrix $S_{cc}(f)$, common-mode to differential-mode scattering matrix $S_{cd}(f)$, differential-mode to common-mode scattering matrix $S_{dc}(f)$, defined by Equation (178A–1) at each measurement frequency f.

$$S(f) = \begin{bmatrix} s_{11}(f) & s_{12}(f) \\ s_{21}(f) & s_{22}(f) \end{bmatrix} \quad (178A\text{-}1a)$$

$$S_{CC}(f) = \begin{bmatrix} s_{cc11}(f) & s_{cc12}(f) \\ s_{cc21}(f) & s_{cc22}(f) \end{bmatrix} \quad (178A\text{-}1b)$$

$$S_{CD}(f) = \begin{bmatrix} s_{cd11}(f) & s_{cd12}(f) \\ s_{cd21}(f) & s_{cd22}(f) \end{bmatrix} \quad (178A\text{-}1c)$$

$$S_{DC}(f) = \begin{bmatrix} s_{dc11}(f) & s_{dc12}(f) \\ s_{dc21}(f) & s_{dc22}(f) \end{bmatrix} \quad (178A\text{-}1d)$$

178A.3 Modal Effective Return Loss

Modal Effective Return Loss (ERL_{CC}, ERL_{CD}, ERL_{DC}) are figures of merit for the modal electromagnetic wave reflections from a device or a channel input or output. Where:

- ERL_{CC} is common -mode to common-mode effective return loss, derived from the return loss measurement $S_{CC11}(f)$
- ERL_{CD} is differential -mode to common -mode effective return loss, derived from the return loss measurement $S_{CD11}(f)$
- ERL_{DC} is common -mode to differential -mode effective return loss, derived from the return loss measurement $S_{DC11}(f)$

ERL_{CC}, ERL_{CD}, and ERL_{DC} shall be calculated using the method described in this annex.

The parameters used to calculate ERL_{CC}, ERL_{CD}, ERL_{DC} are listed in Table 178A–14. The values assigned to these parameters are defined by the Physical Layer specification that invokes the modal ERL method.

178A.3.1 Pulse time-domain reflection signals

ERL_{CC}, ERL_{CD}, and ERL_{DC} are derived respectively from unity pulse time-domain reflection signals $PTDR_{CC}(t)$, $PTDR_{CD}(t)$, and $PTDR_{DC}$. $PTDR_{CC}(t)$, $PTDR_{CD}(t)$, and $PTDR_{DC}$ are defined at the test points defined in the Physical Layer specification that invokes the modal ERL method. $PTDR_{CC}(t)$, $PTDR_{CD}(t)$, and $PTDR_{DC}$ may be acquired directly from an appropriately filtered time domain reflectometer (TDR), or derived mathematically from measured scattering parameters $S(f)$, $S_{cc}(f)$, $S_{cd}(f)$, and $S_{dc}(f)$, cascaded with transmitter and receiver filters, according to the procedure in this subclause. See 178A.1.2 for scattering parameters measurement recommendations including frequency step, start frequency, and stop frequency.

Table 178A–14—ERL parameters

Parameter	Reference	Symbol	Units
Signaling rate	93A.1.1	f_b	GBd
Transition time associated with a pulse	93A.2	T_r	ns
Receiver 3 dB bandwidth	93A.1.4.1	f_r	GHz
Number of signal levels	93A.1.6	L	—
Length of the reflection signal	—	N	UI
Number of samples per unit interval	93A.1.6	M	—
Equalizer length associated with reflection signal	178A.3.2	N_{bx}	UI
Incremental available signal loss factor	178A.3.2	β_x	GHz
Permitted reflection from a transmission line external to the device under test	178A.3.2	ρ_x	—
Target detector error ratio	93A.1.7	DER_0	—

The filtered modal return losses functions $H_{ccii}(f)$, $H_{cdii}(f)$, and $H_{dcii}(f)$, are defined by Equations (178A–61)

$$H_{ccii}(f) = H_t(f)\, s_{ccii}(f)\, H_r(f) \tag{178A–61a}$$

$$H_{cdii}(f) = H_t(f)\, s_{cdii}(f)\, H_r(f) \tag{178A–61b}$$

$$H_{dcii}(f) = H_t(f)\, s_{dcii}(f)\, H_r(f) \tag{178A–61c}$$

Where:

- f is the frequency in GHz
- $H_t(f)$ is the input rise time transfer function defined in 178A.1.6.2
- $H_r(f)$ is the receiver noise filter transfer function defined in 178A.1.6.3
- i is the port index of the scattering parameters, 1 or 2
- $s_{ccii}(f)$ is the channel common-mode return loss
- $s_{cdii}(f)$ is the channel common-mode to differential-mode return loss
- $s_{dcii}(f)$ is the channel differential-mode to common-mode return loss

The modal pulse TDR signals $PTDR_{cc}(t)$, $PTDR_{cd}(t)$, and $PTDR_{dc}(t)$ are defined by Equation (178A–62).

$$PTDR_{cc}(t) = \int_{-\infty}^{\infty} X(f) H_{ccii}(f) \exp(j2\pi f t)\, df \tag{178A–62a}$$

$$PTDR_{cd}(t) = \int_{-\infty}^{\infty} X(f) H_{cdii}(f) \exp(j2\pi f t)\, df \tag{178A–62b}$$

$$PTDR_{dc}(t) = \int_{-\infty}^{\infty} X(f) H_{dcii}(f) \exp(j2\pi f t)\, df \tag{178A–62c}$$

Where:

- t is the time in ns starting from the peak of the injected pulse
- $X(f)$ is defined by Equation (93A–23) with A_t set to 1

178A.3.2 Effective reflection waveform

The effective modal reflection waveforms $R_{cceff}(t)$, $R_{cdeff}(t)$, and $R_{dceff}(t)$ are computed by time gating and weighting the PTDR waveforms $PTDR_{cc}(t)$, $PTDR_{cd}(t)$, and $PTDR_{dc}(t)$ per Equation (178A–63). $R_{cceff}(t)$, $R_{cdeff}(t)$, and $R_{dceff}(t)$ are pure numbers.

$$R_{cceff}(t) = PTDR_{cc}(t) \times G_{rr}(t) \times G_{loss}(t) \tag{178A–63a}$$

$$R_{cdeff}(t) = PTDR_{cd}(t) \times G_{rr}(t) \times G_{loss}(t) \tag{178A–63b}$$

$$R_{dceff}(t) = PTDR_{dc}(t) \times G_{rr}(t) \times G_{loss}(t) \tag{178A–63c}$$

Where:

- $G_{rr}(t)$ is defined in Equation (93a-61)
- $G_{loss}(t)$ is defined in Equation (93a-62)

178A.3.3 Sampled effective reflection

The sampled modal effective reflection for each phase m is computed per Equation (178A–64).

$$h_{cc}^{(m)}(n) = R_{cceff}\left(t_{fx} + \frac{n+m/M}{f_b}\right) \tag{178A–64a}$$

$$h_{cd}^{(m)}(n) = R_{cdeff}\left(t_{fx} + \frac{n+m/M}{f_b}\right) \tag{178A–64b}$$

$$h_{dc}^{(m)}(n) = R_{dceff}\left(t_{fx} + \frac{n+m/M}{f_b}\right) \tag{178A–64c}$$

where

- n is an integer ranging from 0 to N–1
- m is an integer ranging from 0 to M–1
- N and M are supplied by the clause that invokes this method

The standard deviation of the distributions of the modal reflection signals for each phase m for s is defined by Equation (178A–65).

$$\sigma_{cch}^{(m)} = \sqrt{\Sigma_{n=1}^{N}\left(h_{cc}^{(m)}(n)\right)^2} \quad (178A–65a)$$

$$\sigma_{cdh}^{(m)} = \sqrt{\Sigma_{n=1}^{N}\left(h_{cd}^{(m)}(n)\right)^2} \quad (178A–65b)$$

$$\sigma_{dch}^{(m)} = \sqrt{\Sigma_{n=1}^{N}\left(h_{dc}^{(m)}(n)\right)^2} \quad (178A–65c)$$

where

m	is an integer ranging from 0 to M–1
N and M	are supplied by the clause that invokes this method

178A.3.4 x-quantile of the reflection distributions

The modal reflection signal distributions $p_{cc}(y)$, $p_{cd}(y)$, and $p_{dc}(y)$ are computed from the sampled effective reflection using the procedure defined in 93A.1.7.1, with $h_{cc}(n) = h_{cc}^{(m)}(n)$, $h_{cd}(n) = h_{cd}^{(m)}(n)$, or $h_{dc}(n) = h_{dc}^{(m)}(n)$, where m respectively maximizes $\sigma_{cch}^{(m)}$, $\sigma_{cdh}^{(m)}$ or $\sigma_{dch}^{(m)}$. The corresponding cumulative distribution functions $P_{cc}(y)$, $P_{cd}(y)$, and $P_{dc}(y)$ are calculated from replacing $p(y)$ respectively with $p_{cc}(y)$, $p_{cd}(y)$, and $p_{dc}(y)$ in Equation (93A–37). The x-quantile of the distributions, $P_{cc}^{-1}(x)$, $P_{cd}^{-1}(x)$, and $P_{dc}^{-1}(x)$, is the value of y that satisfies the relationship $P_{cc}^{-1}(x) = x$, $P_{cd}^{-1}(x) = x$, or $P_{dc}^{-1}(x) = x$.

178A.3.5 modal ERL

Modal ERLs are defined

$$ERL_{cc} = 20 \times \log 10(P_{cc}^{-1}(DER_0)) \quad (178A–66a)$$

$$ERL_{cd} = 20 \times \log 10(P_{cd}^{-1}(DER_0)) \quad (178A–66b)$$

$$ERL_{dc} = 20 \times \log 10(P_{dc}^{-1}(DER_0)) \quad (178A–66c)$$

where DER_0 is the target detector error ratio.