Document: IEEE802.3dj Modal ERL Proposal

IEEE P802.3dj Task Force

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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),* $S_{cc}(f)$, $S_{cc}(f)$, and $S_{cc}(f)$, 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	—

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

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

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

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

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).

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

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

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

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.

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

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

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

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).

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

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

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

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).

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

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

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

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

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

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

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

where DER_0 is the target detector error ratio.