165. Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, type 25GBASE–T1

165.7 Link segment characteristics

165.7.1 Link transmission parameters

165.7.1.3 Return loss

165.7.1.3.2 Residual echo metric (REM)

This subclause defines a metric to limit noise from echo outside of major discontinuities in a link segment. The echo outside these major discontinuities is referred to as the residual echo. This metric is determined using the procedure in 165.7.1.3.3 using the parameters in Table 165–16:

Table 165–16—REM Parameters

Parameter	Value	Description
Δf	2.5 MHz	The sample frequency spacing for the frequency domain transfer function measurements
N	4096	Number of sampling points to use for the time domain representation of the echo impulse response
N_{seg}	4	Number of samples in each segment
$N_{discard}$	16	Number of largest segments to discard

165.7.1.3.3 Calculating residual echo metric

Step 1 The frequency domain transfer function for the differential mode channel echo, S11, is measured at the link segment side of the MDI with the far end terminated in 100 Ω resistance. For example, if the cable is terminated in a plug, the measurement is on the cabling between the (de-embedded) plug and the far end termination. This measurement is performed for both ends of the link segment and provides the magnitude and phase of the transfer function, measured with frequency spacing Δf. The measured signal can be represented as a complex sequence E_k:

$$E_k = \begin{cases} S_{11}(k\Delta f) \\ S_{22}(k\Delta f) \end{cases} \tag{165–21}$$

Step 2. The frequency domain transfer function is converted to time domain impulse response with sampling interval, T, according to the following method:

Step 2a. The phase of E_k is adjusted to make the values for $k = 0$ and $k = K_N$ real. The adjustment is done by dropping any imaginary component at DC and applying linear phase adjustment to E_k, corresponding to fractional delay of the time domain signal, and is given by:

$$\begin{aligned} H_k &= E_k e^{-jk\theta}, 0 < k \le K_N \\ H_0 &= \text{real}(E_0) \end{aligned} \tag{165–22}$$

where

$$\theta = \frac{angle(E_{K_N})}{K_N}$$
$$K_N = \frac{N}{2} \quad (165–23)$$

Step 2b. The impulse response of the signal is computed by applying Hermitian symmetric extension of the signal for k from K_N+1 to $N–1$, according to Equation (165–24):

$$H_k = conj(H_{K_N - k}) \quad (165–24)$$

where

$$k \in \{K_N + 1, \ldots, 2K_N - 1\} \quad (165–25)$$

and then computing the inverse Fourier transform according to:

$$h_n = \frac{1}{K_N} \sum_{k=0}^{2K_N - 1} H_k e^{j\frac{2\pi kn}{2K_N}} \quad (165–26)$$

Step 3. The first N/2 samples of the echo impulse response, h_n, are split into segments with N_{seg} samples in each segment. The sum of the squares for each segment is computed by adding the squared impulse response in each segment

$$P_r = \sum_{k = rN_{seg}}^{(r+1)N_{seg} - 1} h_k^2 \quad (165–27)$$

Step 4. The $N_{discard}$ largest P_r values are excluded from the calculations by setting their value to zero in the residual echo value

$$RE_r = \begin{cases} 0 \text{ if } P_r \text{ is one of } N_{discard} \text{ largest } P_r \text{ values} \\ P_r \text{ for all other } r \end{cases} \quad (165–28)$$

Step 5. The residual echo metric, REM, is calculated as the sum of all the residual echo values from step 4:

$$REM = 10\log_{10}\left(\sum_r RE_r\right), dB \quad (165–29)$$

165.7.1.3.4 Limit on residual echo metric

The REM value of each end of the link segment, defined by the calculation described in 165.7.1.3.3, shall comply with Equation (165–30):

$$REM(N_{discard}) \le min(REM_{max}, -IL(f_c) - REM_{offset})\ (\text{dB}) \quad (165\text{–}30)$$

where

f_c	is 4 GHz
REM_{max}	is –30 dB
REM_{offset}	is 20 dB

165.7.1.3.5 Echo tail metric (ETM)

This subclause defines a metric to limit the distribution in time of echo outside major discontinuities in a link segment. This is referred to as the echo tail, and the echo tail metric is determined using the procedure in 165.7.1.3.6 using the parameters in Table 165–17:

Table 165–17—ETM Parameters

Parameter	Value	Description
Δf	2.5 MHz	The sample frequency spacing for the frequency domain transfer function measurements
N	4096	Number of sampling points to use for the time domain representation of the echo impulse response
N_{seg}	4	Number of samples in each segment
$N_{discard\_etm}$	6	Number of largest segments to discard for ETM calculations

165.7.1.3.6 Calculating echo tail metric

Step 1. Perform steps 1 & 2 as specified in 165.7.1.3.3 to compute the time domain impulse response for the echo, h_n, from frequency domain measurements of the differential mode channel echo, S11, which is measured at the link segment side of the MDI with the far end terminated in 100 Ω resistance.

Step 2. Determine the time span of the echo response to the far-end termination from the frequency domain measurements of the insertion loss which are represented as complex sequences $IL_{k,i}$:

$$IL_{k,1} = S_{21}(k\Delta f)$$
$$IL_{k,2} = S_{12}(k\Delta f) \quad (165\text{–}31)$$

Step 2a. Identify the unwrapped phase of the frequency response as:

$$\theta_{k,i} = unwrap(angle(IL_{k,i})) \quad (165\text{–}32)$$

Step 2b. Estimate the propagation delay by calculating the slope from a linear fit to the phase as:

$$d_i = \frac{N}{2\pi N_{seg}} \times \frac{M\sum_{k=k_s}^{k_s+M-1}(k \times \theta_{k,i}) - \left(\sum_{k=k_s}^{k_s+M-1} k\right) \times \left(\sum_{k=k_s}^{k_s+M-1} \theta_{k,i}\right)}{M\sum_{k=k_s}^{k_s+M-1} k^2 - \left(\sum_{k=k_s}^{k_s+M-1} k\right)^2} \tag{165–33}$$

With $k_s = 40$, and $M = 1600$, the linear fit is calculated over the frequency range of 100 MHz to 4.1 GHz. The propagation delay, d_i, is expressed in terms of number of segments.

The span of the echo response is the round-trip delay or twice the propagation delay:

$$L_e = 2 \times floor(min(d_1, d_2)) \tag{165–34}$$

Step 3. Repeat steps 3a through 3d iteratively for each integer value of m from <u>m</u> = m_s = 13 to $m = m_e$ =154 to compute ETM(m).

Step 3a. Define the partial echo response at point m as:

$$g_n^{\ m} = \begin{cases} 0 & n < m \\ h_n & m \le n < L_e \\ 0 & L_e \le n \end{cases}$$

, where h_n is the time domain impulse response of the echo computed in step 1. (165–35)

Step 3b. The first N/2 samples of the partial echo impulse response, $g_n^{\ m}$, are split into segments with N_{seg} samples in each segment. The sum of the squares for each segment is computed by adding the squared impulse response in each segment

$$P_r^m = \sum_{k=rN_{seg}}^{(r+1)N_{seg}-1} \left(g_k^m\right)^2 \tag{165–36}$$

Step 3c. The $N_{discard\_etm}$ largest $P^m{}_r$ values are excluded from the calculations by setting their value to zero in the echo tail value

$$ET_r(m) = \begin{cases} 0 \text{ if } P_r^m \text{ is one of } N_{discard\_etm} \text{ largest } P^m{}_r \text{ values} \\ P^m{}_r \text{ for all other } r \end{cases} \tag{165–37}$$

Step 3d. The echo tail metric for lag m, ETM(m), is calculated as the sum of the echo tail values from step 3c:

(165–38)

$$ETM(m) = 10\log_{10}\left(\sum_r ET_r(m)\right), dB$$

165.7.1.3.7 Limit on echo tail metric

The ETM value of each end of the link segment, defined by the calculation described in 165.7.1.3.6, shall comply with Equation (165–39):

$$ETM(m) \le REM_{Limit} - 16 \times \frac{m - m_s}{m_e - m_s} \quad m_s \le m < m_e \quad \text{(dB)} \qquad (165\text{–}39)$$

where REM_{Limit} is the limit of REM as defined in the right-hand side of Equation (165–30), $m_s = 13$, and $m_e = 154$.

165.11 Protocol implementation conformance statement (PICS) proforma for Clause 165, Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, type 25GBASE–T1[6]

165.11.4 PICS proforma tables for Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA) sublayer, and baseband medium, type 25GBASE–T1

165.11.4.5 Link segment characteristics

Item	Feature	Subclause	Value/Comment	Status	Support
LSC1	Insertion loss	165.7.1.1	See Equation (165–19)	M	Yes [ ]
LSC2	Return loss	165.7.1.3.2	See Equation (165–20)	M	Yes [ ]
LSC3	Residual Echo Metric	165.7.1.3.7	See Equation (165–30)	M	Yes [ ]
LSC4	Echo Tail Metric	165.7.1.3.7	See Equation (165–39)	M	Yes [ ]
LSC5	Coupling attenuation	165.11	See Equation (165–37)	INS:M	Yes [ ] N/A [ ]
LSC6	Maximum link delay	165.7.1.6	Not to exceed 94 ns at all frequencies between 2 MHz and 9000 MHz	M	Yes [ ]
LSC7	PSANEXT	165.7.2.1	See Equation (165–38)	M	Yes [ ]
LSC8	PSAACRF	165.7.2.2	See Equation (165–39)	M	Yes [ ]

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