165.7.1.3.2 Echo Tail and Residual Echo Metrics

This subclause defines metrics to limit Noise from echo outside of major discontinuities in a link segment. Such echo that is beyond the required capability of the PHY to cancel the echo is referred to as residual echo. These metrics are determined using the following procedure using the parameters in Table 165-16.

Table 165–16—XXX

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
Nseg	4	Number of samples in each segment
Ndiscard	16	Number of largest segments to discard
Ndiscard_etm	6	Number of largest segments to discard for ETM calculations

Step 1 The frequency domain transfer function for the differential mode channel echo, S11, is measured at the link segment side of the MDI, e.g., the plug if the cable is terminated in a plug, with the far end terminated in 100Ω resistance. 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:

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

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 at DC and Nyquist frequencies 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:

$$H_k = E_k e^{-jk\theta}$$
$$H_0 = \mathrm{real}(E_0)$$

where

$$\theta = \frac{angle(E_{K_N})}{K_N}$$

$$K_N = \frac{K}{2}$$

Step 2b. The impulse response of the signal is computed by applying Hermitian symmetric extension of the signal above the Nyquist frequency, as in Equation xxx-3:

$$H_k = conj(H_{K_N - k})$$

where

$$k \in \{K_N + 1, \ldots, 2K_N - 1\}$$

and then computing the inverse Fourier transform according to:

$$h_n = \frac{1}{K_N} \sum_{k=0}^{2K_N - 1} H_k e^{j\frac{2\pi}{2K_N}kn}$$

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

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

Step 4. The k largest Pr values are excluded from the calculations by setting their value to zero in the residual echo value

$$RE_k(k) = \begin{cases} 0 \text{ if } P_r \text{ is one of } k \text{ largest } P_r \text{ values} \\ P_r \text{ for all other } r \end{cases}$$

Step 5. The residual echo metric, REM, is calculated as the sum of all the residual echo values, after discarding the k largest P_k values:

$$REM(k) = 10\log_{10}\left(\sum_r RE_r(k)\right), dB$$

Step 6 Determine the time span of the echo response from the frequency domain measurement of the insertion loss which is represented as a complex sequence H_k:

$$\begin{cases} H_{k,1} = S_{21}(k\Delta f) \\ H_{k,2} = S_{12}(k\Delta f) \end{cases}$$

Step 6a. Identify the unwrapped phase of the frequency response as:

$$\theta_{k,i} = unwrap(\, angle(H_{k,i})\,)$$

Step 6b. Estimate the propagation delay by calculating the slope from a linear fit to the phase as:

$$d_i = \frac{N}{2\pi N_{seg}} \frac{N_k \sum_{k=k_s}^{k_s+N_k-1}(k \times \theta_{k,i}) \; - \; \left(\sum_{k=k_s}^{k_s+N_k-1} k\right) \times \left(\sum_{k=k_s}^{k_s+N_k-1} \theta_{k,i}\right)}{N_k \sum_{k=k_s}^{k_s+N_k-1} k^2 \; - \; \left(\sum_{k=k_s}^{k_s+N_k-1} k\right)^2}$$

With $k_s = 40$, and $N_k = 1600$, 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:

$$L_e = 2 \times floor(\, min(d_1, d_2)\,)$$

Step 7 Define the partial echo response at point m as:

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

Step 8 Apply steps 3, 4 and 5 to partial response g_n^m (instead of h_n) to calculate the associated REM. The $ETM(m)$ is this REM evaluated at $N_{discard\_etm}$.

165.7.1.3.3 Limit on Residual Echo Metric (REM)

The REM value of each end of the link segment, defined by the calculation described in 165.7.1.3.2, shall comply with Equation (165-35):

$$REM(N_{discard}) \leq min(REM_{max}, -IL(f_c) - REM_{offset}) \text{ (dB)}$$

where

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

165.7.1.3.4 Limit on Echo Tail Metric (ETM)

The ETM value of each end of the link segment, defined by the calculation described in 165.7.1.3.2, shall comply with (165-36):

$$ETM(m) \leq \begin{cases} REM_{Limit} - 16 \times \dfrac{m - m_s}{m_e - m_s} \; dB & m_s \leq m < m_e \\ REM_{Limit} - 16 \; dB & m_e \leq m \end{cases}$$

Where REM_{Limit} is the limit of REM as defined in (165-35), $m_s = 13$, and $m_e = 154$.