Metrics for Micro-Reflection Limit

Contribution to IEEE 802.3cy

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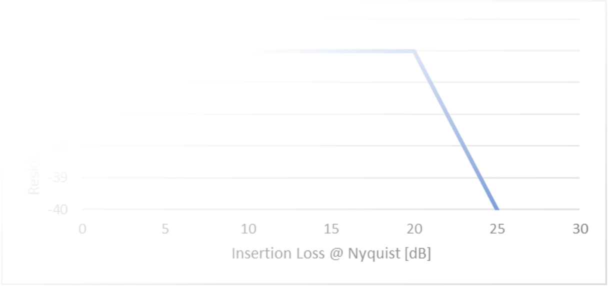
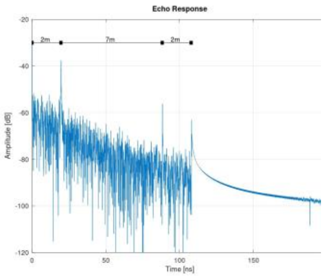
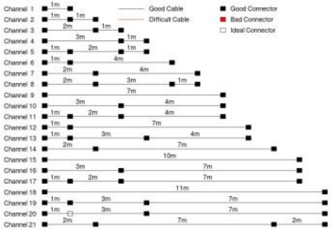
Introduction

- There have been several presentations on limiting micro-reflections:
  - jonsson_3cy_01a_0720
  - sedarat_3cy_01_0920
  - jonsson_3cy_01a_10_14_20
  - sedarat_3cy_02_10_14_20
  - sedarat_3cy_02_1120
  - jonsson_3cy_01_12_08_20
  - sedarat_3cy_01_03_23_21
- Specific text for calculating the micro-reflection limits was proposed in
  - jonsson_3cy_01_03_16_21
- This contribution presents updated text, based on feedback on the earlier text proposal
- This contribution does NOT propose specific limits to use in the text







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xxx.1 Echo Tail and Residual Echo Metrics

Noise from echo outside of major discontinuities in a link segment, beyond the capability required of the PHY to cancel echo is referred to as residual echo. To ensure the total residual echo energy is limited, two figures of merit denoted as the Echo Tail Metric (ETM) and the Residual Echo Metric (REM) are specified. The REM is the remaining energy of a reflected impulse response after the largest time domain peaks of the reflected signal are removed. The ETM is the remaining energy of the reflected impulse after largest time domain peaks and the first samples of the echo time domain response have been removed.

The ETM and REM are determined using the following four-step procedure using the parameters in Table 1:

Table 1

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

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Step 1. The frequency domain transfer function for the differential mode channel echo, S_{11}, 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:

(Equation xxx-1)

$$E_k = S_{11}(k\Delta f)$$

or

$$E_k = S_{22}(k\Delta f)$$

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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:

(Equation xxx-2)

$$H_k = E_k e^{-jk\theta}$$

$$H_0 = \mathrm{real}(E_0)$$

where

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

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

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:

(Equation xxx-3)

$$H_k = \mathrm{conj}\left(H_{K_N-k}\right), \qquad \text{for } k \in \{K_N+1, \dots, 2K_N-1\}$$

and then computing the inverse Fourier transform according to:

(Equation xxx-4)

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

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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

(Equation xxx-5)

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

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Step 4. The ETM and REM are calculated according to the following method:

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

(Equation xxx-6)

$$RE_k(N_{discard}) = \begin{cases} 0 & \text{if } P_k \text{ is one of } N_{discard} \text{ largest } P_k \text{ values} \\ P_k & \text{for all other } k \end{cases}$$

Step 4b. The echo tail metric is calculated as the sum of all the residual echo values after a reference value *k*

(Equation xxx-7)

$$ETM(k) = 10\log_{10}\left(\sum_{r \geq k} RE_r(N_{discard})\right) \quad \text{(dB)}$$

Step 4c. The residual echo metric, REM, is calculated as the sum of all the residual echo values, after discarding the *k* largest P_k values:

(Equation xxx-8)

$$REM(k) = 10\log_{10}\left(\sum_{r} RE_r(k)\right) \quad \text{(dB)}$$

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xxx.2 Limit on Residual Echo Metric

The REM value of each end of the link segment, defined by the calculation described in Section xxx.1, shall comply with Equation xxx-9:

(Equation xxx-9)

$$REM(N_{discard}) \leq \min(REMmax, -IL(f_c) - REMoffset) \quad (dB)$$

where *REMmax* is TBD and *REMoffset* is TBD.

xxx.3 Limit on Echo Tail Metric

The ETM value of each end of the link segment, defined by the calculation described in Section 1, shall comply with Equation xxx-10:

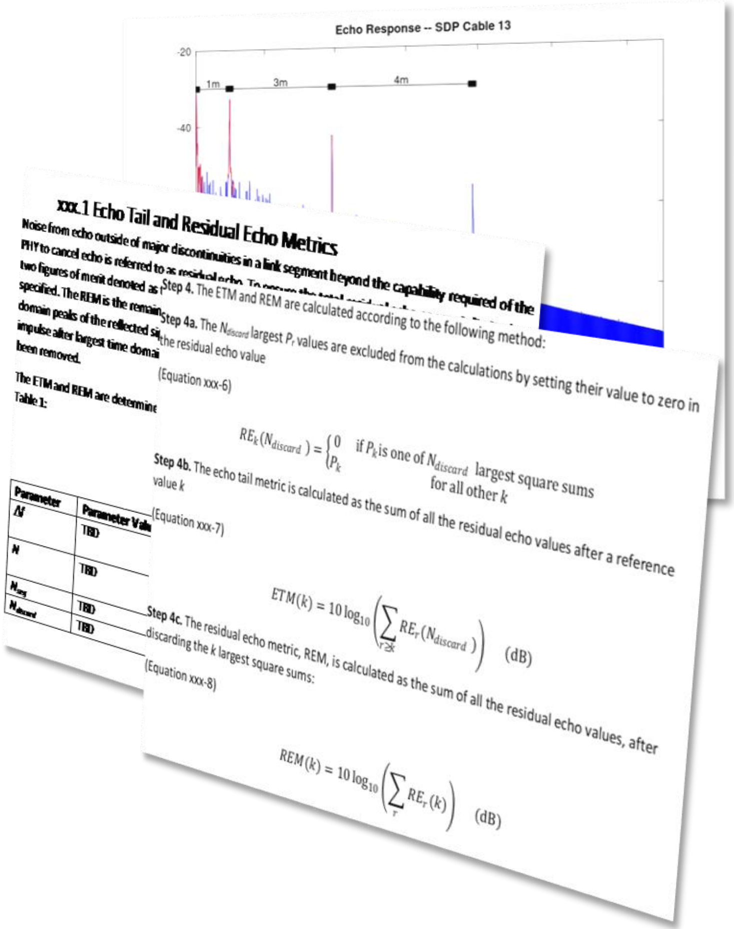
(Equation xxx-10)

$$ETM(k) \leq \min\big(ETMmax, -IL(f_c) - ETMoffset(k)\big) \quad for\ k\ \in TBD$$

where *ETMmax* is TBD and *ETMoffset(k)* is TBD.

Main Changes from Previous Text

- Fewer parameters in Table 1
- Interpolation of S11 parameters have been removed and replace with direct requirement on the frequency spacing in the measurements
- New Echo Tail Metric (ETM) added and is similar to metric described in [sedarat_3cy_01_03_23_21]
- The Residual Echo Metric (REM) has been parameterized*



* Note that $REM(N_{discard}) = ETM(0)$

Example Code

```
function [REM,ETM] = jonsson_3cy_01_03_23_21(f,s11,N_bins,N_seg,N_discard)

%%% number of samples to use %%%
K_N = N_bins * N_seg;
N_samples = K_N*2;  %even number of samples

%%% calculate echo impulse response and power %%%
h_echo = jonsson_3cy_01_03_23_21_f2t(s11,f,N_samples);

%%% find power in each time bin %%%
h2 = h_echo.^2;
P_k = zeros(1,N_bins);
m1 = 0;
for n=1:N_bins,
  m0 = m1 + 1;
  m1 = round(n*N_seg);
  P_k(n) = mean(h2(m0:m1))*(N_seg);
end

%%% find residual echo metric %%%
[p_sort,sort_ix] = sort(P_k);
p_sum = cumsum(p_sort);
REM = 10*log10(p_sum(end:-1:1));

%%% find residual echo RE_k %%%
RE_k = P_k;
RE_k(sort_ix(1:N_discard)) = 0;

%%% calculate echo tail metric %%%
tmp = cumsum(RE_k(end:-1:1));
ETM = 10*log10(tmp(end:-1:1));

end %%% End of jonsson_3cy_01_03_23_21
%%% %%% %%% %%% %%% %%% %%% %%% %%% %%% %%% %%% %%% %%% %%% %%% %%% %%%


function h_n = jonsson_3cy_01_03_23_21_f2t(H,f,N)

%%% re-shape arguments %%%
E_k = H(:);

%%% adjust phase of frequency response %%%
K_N = ceil(N/2);
ang_N = angle(E_k(K_N+1));
x0 = ang_N/(pi);
E_k = E_k.*exp(-j*2*pi*x0*[0:K_N]/K_N/2);
E_k(1) = real(E_k(1));
H_k = [E_k(1:K_N) real(E_k(K_N+1)) conj(E_k(K_N:-1:2))];

%%% find impulse response from IDFT %%%
h_n = real(ifft(H_k));

end %%% End of jonsson_3cy_01_03_23_21_t2t
```

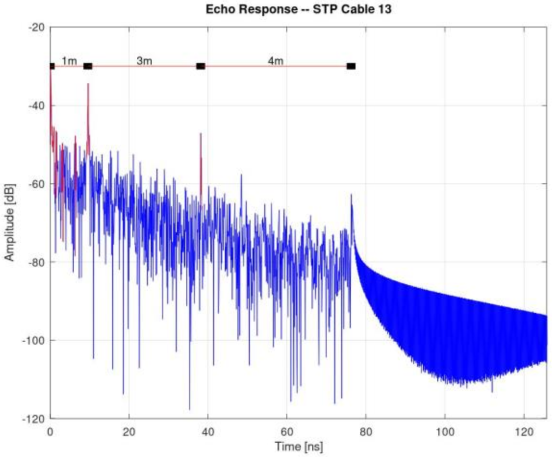
This is experimental code that is provided "as is".

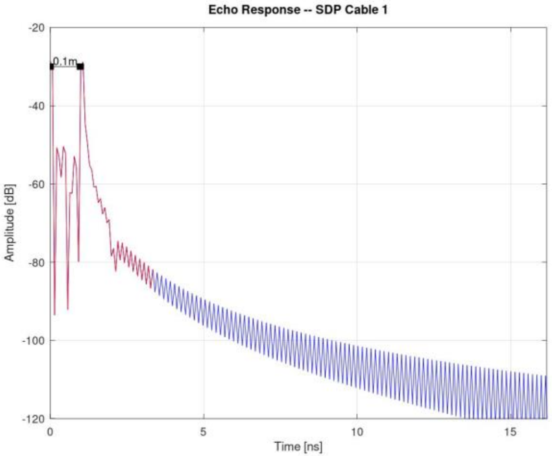
Example Limits

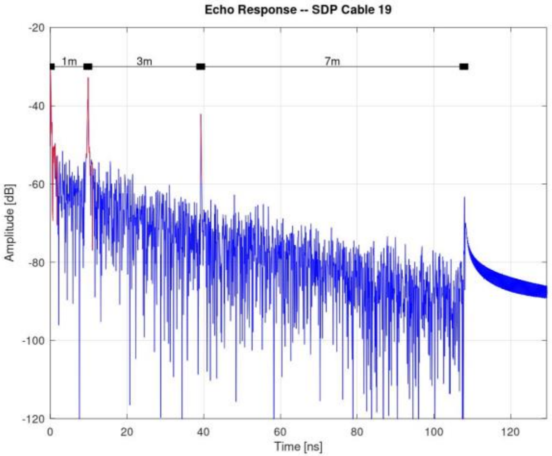
The examples are given for reference only and are not part of the text proposal

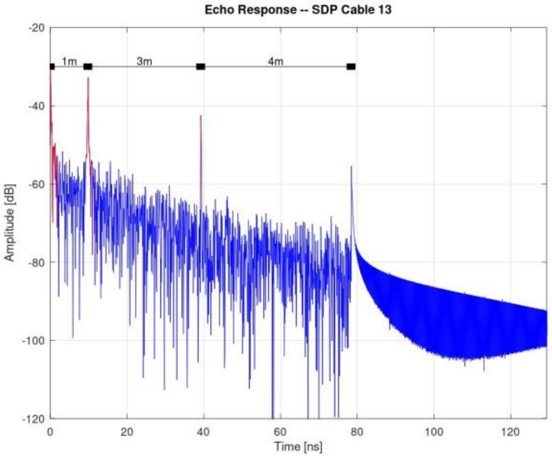
Discarding Echo Peaks (Step 4a)

- The peaks shown in red in the plots are the ones that are removed from the REM and ETM calculations
- Notice the difference between SDP and STP Cable 13
- Notice that Cable 1 is 0.1m long
- Note that this $N_{discard}$ value is **just an example**



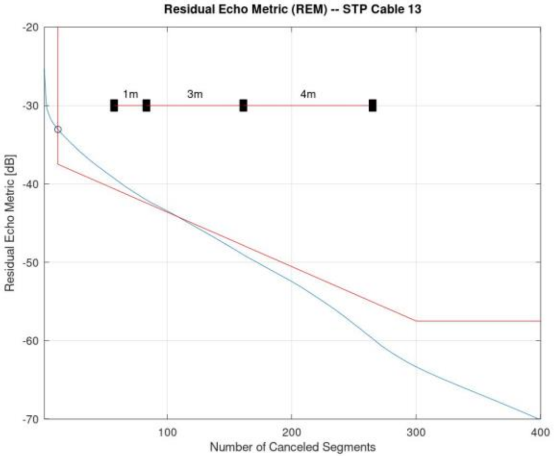


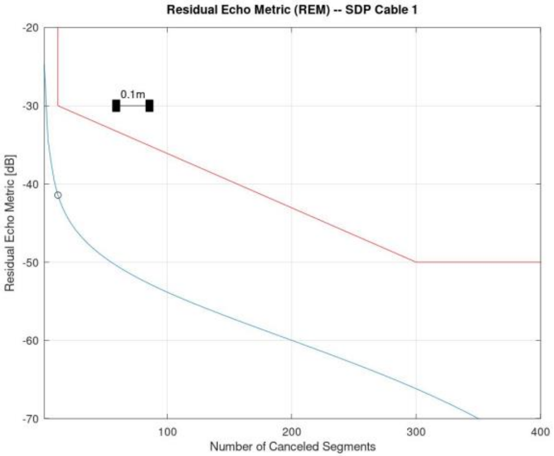


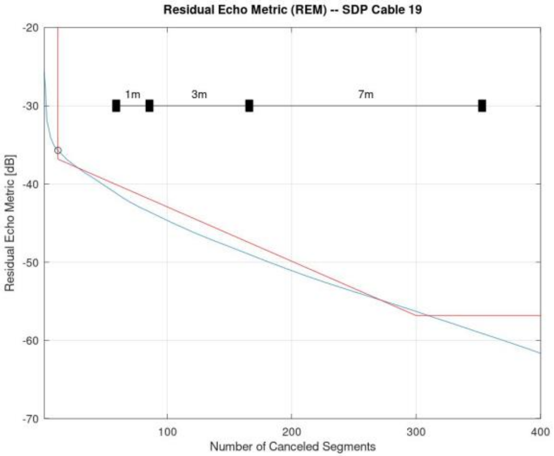


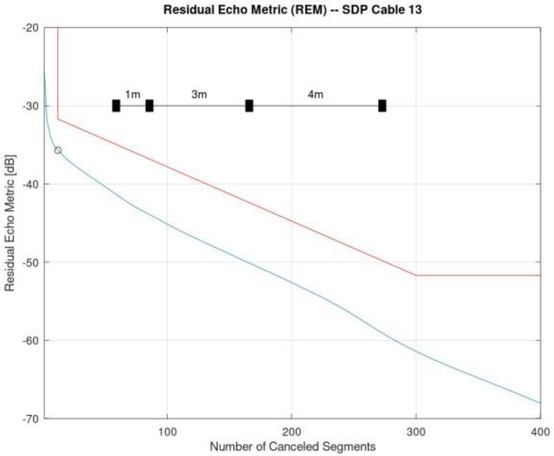
REM Limit Examples

- The plots show possible limits for the REM (blue line)
- The circle represents possible single point test
- The red line represents possible mask for the REM
- Note that these limits are **just examples**



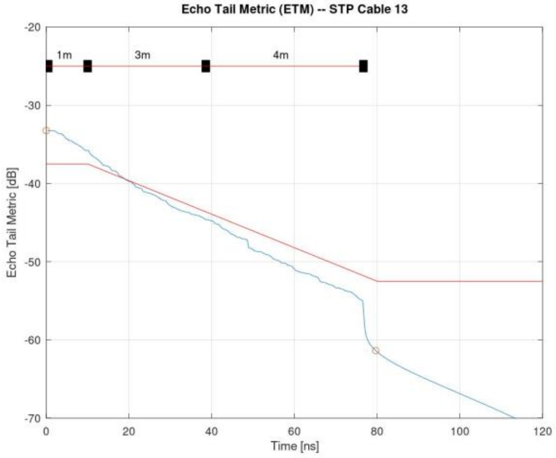


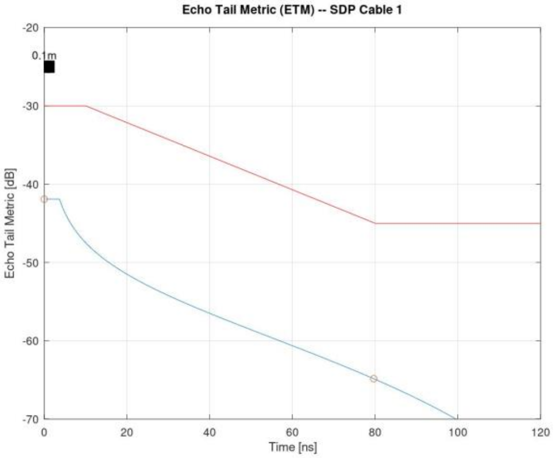


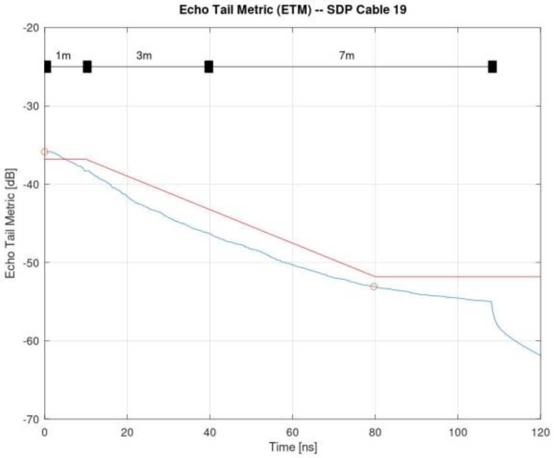


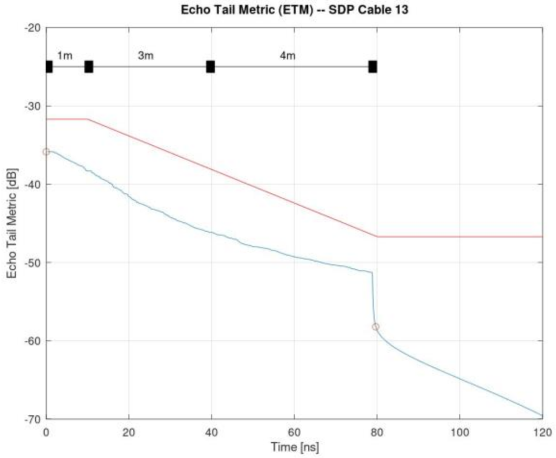
ETM Limit Examples

- The plots show possible limits for the ETM (blue line)
- The circles represents possible single point test
- The red line represents possible mask for the ETM
- Note that these limits are **just examples**









Conclusion

The micro-reflection limit text has been updated based on comments received on earlier text

The code examples have been updated to reflect the updates to the text

Examples are given of how the limits can be defined

We plan to propose to adopt the text in slides 3 to 8 as baseline text in 802.3cy

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