Test Symbol Error Extrapolation

Addressing comments: 226 296 106

Eric Maniloff – Ciena
Mike Dudek – Marvell
Guangcan Mi - Huawei
Adee Ran – Cisco
Roberto Rodes – Coherent

802.3dj interim

May, 2026 Munich, Germany

Overview

Clause 180.9.15 calls out extrapolation of the measured symbol errors in order to reduce test time.

- This is an informative note, not replacing the normative FLR requirement.

Since the symbol error bin probabilities are not likely to be linear, extrapolation beginning at the measured 1 symbol-error/block probability will reduce the accuracy of the extrapolation

Two related comments were submitted on Clause 180.9.15 on D3.0 with different solutions, the intent of this contribution is to facilitate comment resolution.

Additionally, a related comment on the electrical spec was submitted, pointing to the optical definition for guidance.

Current text:

> NOTE—If the statistical projection is modeled accurately by a linear fit extrapolation, a means to provide statistical projection of the measured histograms (see174A.9.3) in order to reduce test time follows. Extrapolate the measured histogram to $H_m^{(i)}(16)$ using a line determined by a linear fit of $\log_{10}(H_m^{(i)}(k))$, for $k = 1$ to n, where n is the largest value of k, where all bins from 0 to n have a count greater than 2.

Receiver Error mask

Table 180–20—Receiver error mask

Test symbol errors per test block, k (see 174A.9.5)	Probability $H_{max}(k)$			
	$p = 1$	$p = 2$	$p = 4$	$p = 8$
1	3.6×10^{-1}	3.3×10^{-1}	2.3×10^{-1}	1.3×10^{-1}
2	2.2×10^{-1}	1.0×10^{-1}	3.5×10^{-2}	1.0×10^{-2}
3	9.2×10^{-2}	2.1×10^{-2}	3.6×10^{-3}	5.1×10^{-4}
4	2.8×10^{-2}	3.3×10^{-3}	2.7×10^{-4}	1.9×10^{-5}
5	7.0×10^{-3}	4.0×10^{-4}	1.6×10^{-5}	5.5×10^{-7}
6	1.4×10^{-3}	4.1×10^{-5}	8.2×10^{-7}	1.3×10^{-8}
7	2.5×10^{-4}	3.5×10^{-6}	3.5×10^{-8}	2.7×10^{-10}
8	3.9×10^{-5}	2.7×10^{-7}	1.3×10^{-9}	4.7×10^{-12}
9	5.2×10^{-6}	1.8×10^{-8}	4.1×10^{-11}	7.1×10^{-14}
10	6.4×10^{-7}	1.1×10^{-9}	1.2×10^{-12}	9.6×10^{-16}
11	7.1×10^{-8}	5.8×10^{-11}	3.1×10^{-14}	1.2×10^{-17}
12	7.2×10^{-9}	2.9×10^{-12}	7.5×10^{-16}	1.3×10^{-19}
13	6.7×10^{-10}	1.3×10^{-13}	1.6×10^{-17}	1.2×10^{-21}
14	5.8×10^{-11}	5.6×10^{-15}	3.3×10^{-19}	1.1×10^{-23}
15	4.7×10^{-12}	2.2×10^{-16}	6.1×10^{-21}	9.1×10^{-26}
16	3.8×10^{-13}	8.3×10^{-18}	1.1×10^{-22}	6.9×10^{-28}

Cl **180** *SC* **180.9.15** *P* **491** *L* **18** # I-226

Maniloff, Eric Ciena Corporation

Comment Type **TR** *Comment Status* **X**

Current text for block error extrapolation performs a linear fit from 1 to n. Because this is unlikely to be linear, it would be more accurate to only extrapolate over the 4 highest bins with sufficient counts.

SuggestedRemedy

Replace: "If the statistical projection is modeled accurately by a linear fit extrapolation, a means to
provide statistical projection of the measured histograms (see174A.9.3) in order to reduce test time
follows. Extrapolate the measured histogram to Hm(i)(16) using a line determined by a linear fit of
log10(Hm(i)(k)), for k = 1 to n, where n is the largest value of k, where all bins from 0 to n have a count
greater than 2."

With

"If the statistical projection is modeled accurately by a linear fit extrapolation, a means to provide statistical projection of the measured histograms (see174A.9.3) in order to reduce test time follows. Extrapolate the measured histogram to Hm(i)(16) using a line determined by a linear fit of log10(Hm(i)(k)), for k = n-3 to n, where n is the largest value of k, where all bins from n-3 to n have a count greater than 2." Make similar changes in Clauses 181, 182, 183.

Proposed Response *Response Status* **O**

Cl **180** *SC* **180.9.15** *P* **491** *L* **18** # I-296

Dudek, Michael Marvell

Comment Type **T** *Comment Status* **X**

The note could be misinterpreted as suggesting extrapolation is also needed for higher probabilites resulting in failures with random errors where the measurements meet the requirement without extrapolation

SuggestedRemedy

Insert "for Hm(i)(k) less than 10^-6"before "Extrapolate the measured histogram......" Also in 180.9.16. Make the equivalent changes in clauses 181, 182 and 183 .

Proposed Response *Response Status* **O**

Related Electrical Comment

A related comment on extrapolation in Annex 176C was contributed

This comment should be addressed along with the optical comments.

Cl **176C** *SC* **176C.6.4.4** *P* **803** *L* **32** # I-106

Ran, Adee Cisco Systems, Inc.

Comment Type **TR** *Comment Status* **X**

For p=1, measurement of block error ratio for validation of the requirements for AUI-C2C (Table 176C-6, probability lower than Hmax for all values of k), even with corrected values of Hmax per another comment, would take more than 1e20 years (for k=16), which is not quite feasible.
For p>1 the required times are even longer.

This means the test cannot be declared to pass without some kind of extrapolation of the measurement.

Similar concerns exist for AUI-C2M (Table 176D-10), KR (Table 178-11) and CR (Table 179-13). Although for KR and CR the test times for p=1 may be feasible, p=2 would still require more than a year to verify.

A spreadsheet for the calculation will be contributed.

SuggestedRemedy

Add the following NOTE after Table 176C-6, based on 180.9.16:

NOTE—If the statistical projection is modeled accurately by a linear fit extrapolation, a means to provide statistical projection of the measured histograms (see 174A.9.3) in order to reduce test time follows. Extrapolate the measured histogram to Hm(i)(16) using a line determined by a linear fit of log10(Hm(i)(k)), for k = 1 to n, where n is the largest value of k for which all bins from 0 to k have a count greater than 2.

Add similar notes after Table 176D-10, Table 178-11, and Table 179-13.

Proposed Response *Response Status* **O**

More details

Data points with test blocks containing > 2 of a symbol error count are used to extrapolate

- Currently this is done from 1 to n where n is the largest bin with > 2 counts of a n symbol errors/test block
- This results in inaccurate extrapolation

Comment 226 proposes using the 4 points with the highest number of symbol errors > 2 counts

- Extrapolation uses bins n-3 to n instead of 1 to n

Comment 296 proposes using points with probability ≤ 1e-6

- This will result in varying numbers of points, typically 3

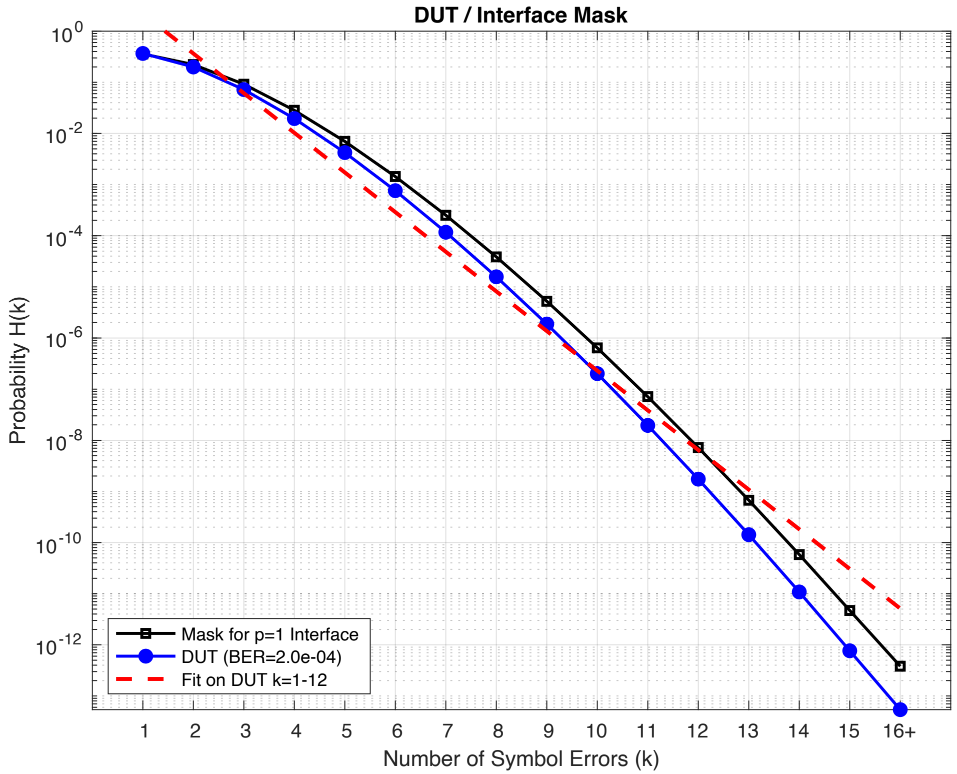
ran_3dj_elec_01_240822 analyzed Symbol Error histograms with added Tx jitter versus LPF BW

- https://www.ieee802.org/3/dj/public/adhoc/electrical/24_0822/ran_3dj_elec_01a_240822.pdf

Key points from data

- With random errors the slope becomes steeper as bin count increases
- With added jitter the slope can become less steep as bin count increases

Example of current definition



The figure shows the Symbol error mask in black

The blue line shows expected probabilities for a DUT BER of 2e-4 assuming random errors

- For a 1 min test ~4 instances of 12 symbol errors are expected for a single lane 212G interface

The red line is a linear fit from 1 to 12 symbol errors

- This is the extrapolation defined in D3.0

Improved fitting

Only using the bins with the highest symbol errors for the extrapolation will improve the fit

For a BER of 2e-4 with random errors bin 12 has an expected count of 4 events

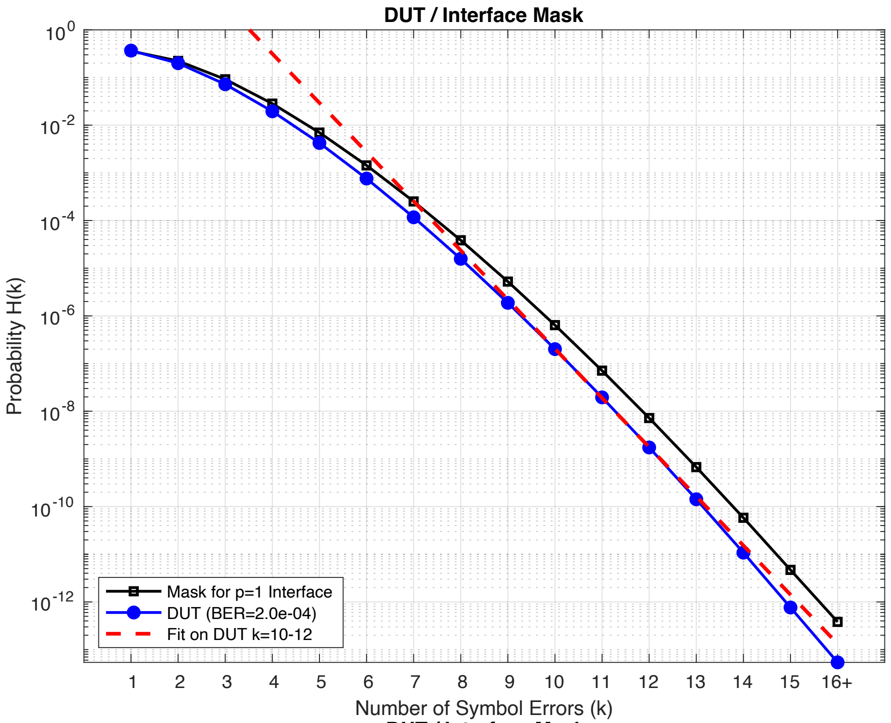
- Top: Fit using k = 10-12, based on bin 12 having > 2 occurrences

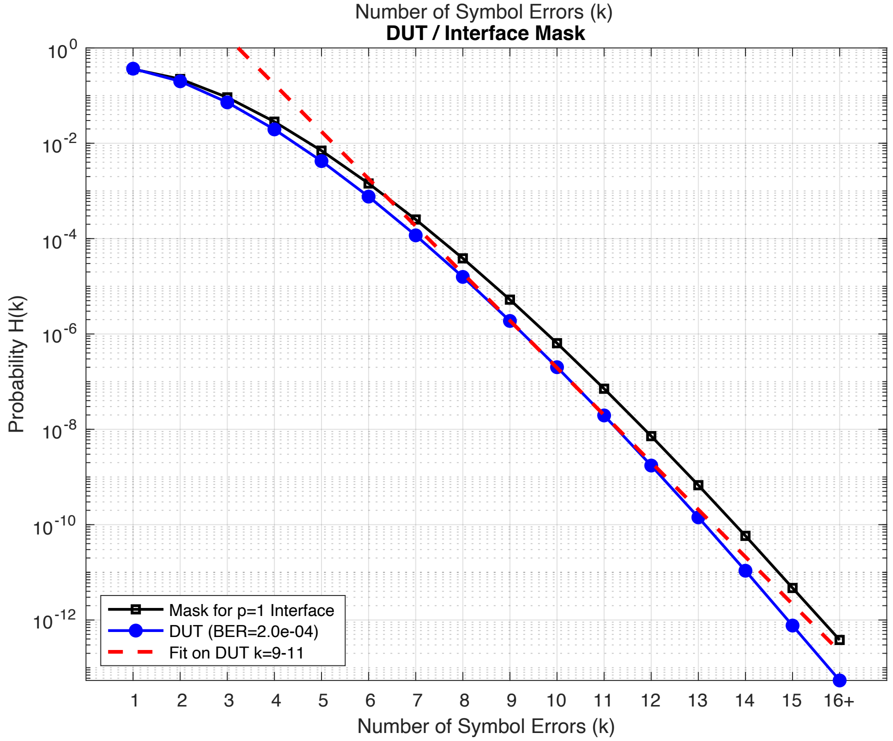
Bottom plot:

- Fit on k= 9-11, since bin 12 has ≈33% probability of ≤ 2 counts

Both extrapolations are an improvement

- Using a criteria of 3 counts for the highest bin allows for more variability than is desirable





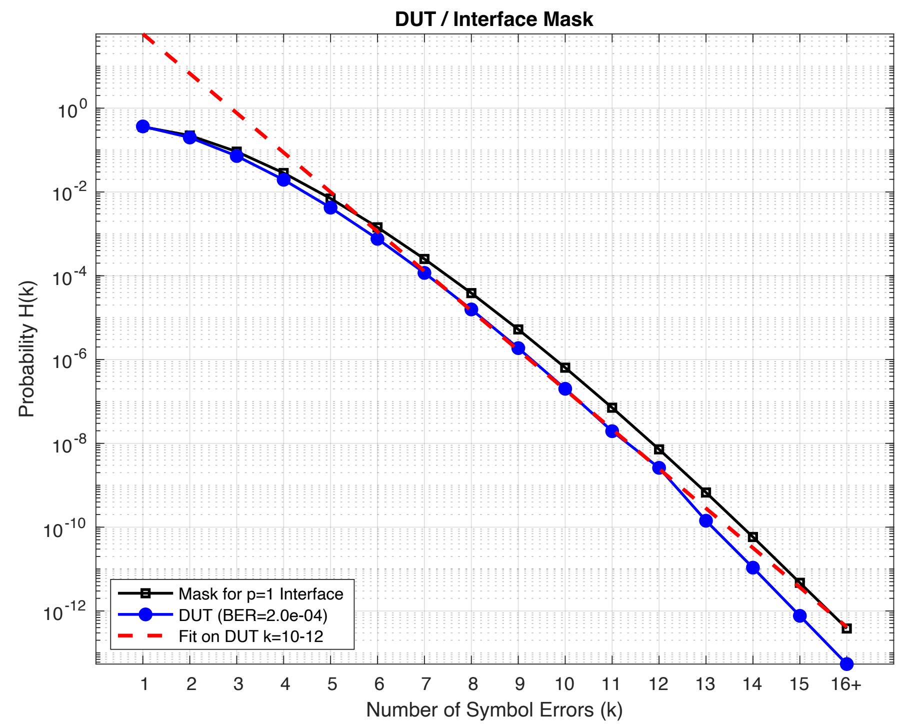
Highest Bin statistical variation

Because the points used in current definition are those with only 3 events, there will be variations in last point

On the right curves for a 2E-4 BER are shown, with bin 12 being a 10% probability (mean = 4, ≥ 6 counts ~12% probability)

Using 3 counts in highest bin allows too much variability

Recommend truncating the data for extrapolation to > 9 counts

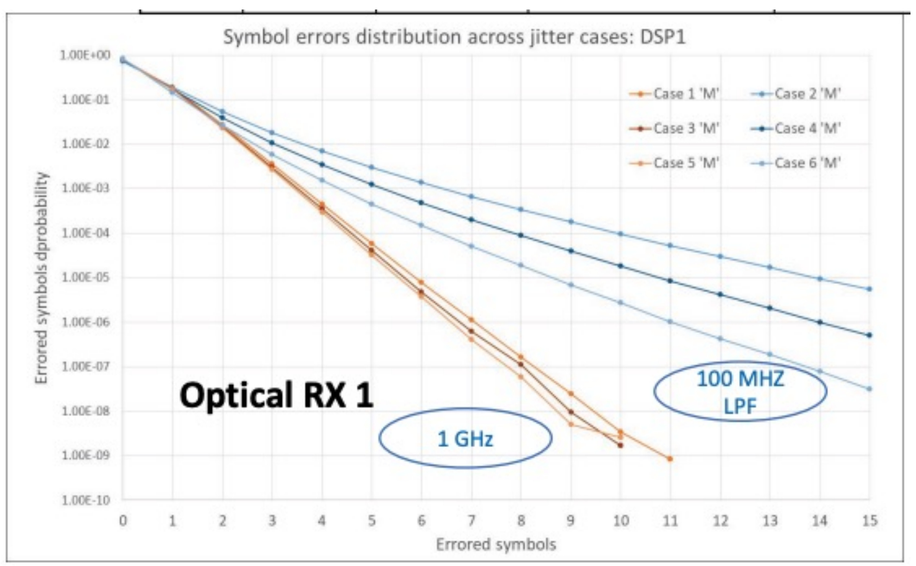


Impact of correlated errors

In ran_3dj_elec_01a_240822 the impact of correlated errors on the symbol error distribution is considered

- Tx jitter is used to generate correlated errors.
- https://www.ieee802.org/3/dj/public/adhoc/electrical/24_0822/ran_3dj_elec_01a_240822.pdf

The change in slope can be used to evaluate performance



rodes_3dj_02a_2605 provides data showing the impact of slope on extrapolations:
https://www.ieee802.org/3/dj/public/26_05/rodes_3dj_02a_2605.pdf

Key message is that in addition to ensuring that the measured data extrapolates to meet the symbol error requirements at bin 16, it is also useful to check that increasing slope isn't going to cause a failure.

Updated definition

Replace

NOTE—If the statistical projection is modeled accurately by a linear fit extrapolation, a means to provide statistical projection of the measured histograms (see174A.9.3) in order to reduce test time follows. Extrapolate the measured histogram to $H_m^{(i)}(16)$ using a line determined by a linear fit of $\log_{10}(H_m^{(i)}(k))$, for $k = 1$ to n, where n is the largest value of k, where all bins from 0 to n have a count greater than 2.

With

Note – In order to predict whether a receiver meets the BLER requirement in a short test time, extrapolation of the measured histogram (see 174.A.9.3) to Hm(16) can be performed. One way of doing this is using a linear fit of log10(Hm(k)) for k = (n-2) to n, where these values of k are the three highest bins having a count of 10 or more. If the slope of the histogram over the measured bins is increasing, it can be an indication of not meeting the BLER requirement. To verify that the slope is not increasing, the values of (log10(Hm(k))-log10(Hm(4))/(k-4) should be less than (log10(Hm(4))-log10(Hm(2))/2 for k greater than 4.

Summary

The current approach to extrapolation defined in 180.9.15 using all bins with > 2 symbol error counts does not provide accurate extrapolation

Language is proposed to modify the extrapolation:

- Only bins with ≥ 10 counts are included
- Only the 3 highest bins measured are used in the extrapolation
- An additional test to verify that the slope is decreasing is described

This update does not modify the normative requirement, but does improve the definition in the informative note

Thanks!