J4u03 improvements for 212Gbps (179.9.4.6.2 J4u03 proposed revisions)

IEEE P802.3dj Plenary (10-14 Nov 2025) Bangkok

Associated comments (P802.3dj D2.2): 276, 358, 201, 207, 224

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Based on draft release of IEEE P802.3dj™/D2.2

Abstract: J4u03 methodology as presently outlined in clause 179.9.4.6.2 (D2.2) exhibits sensitivity to channel loss induced jitter magnification.   This proposal is a continuation of the January 9'th 2025 presentation: https://www.ieee802.org/3/dj/public/adhoc/optics/0125_OPTX/gines_3dj_optx_01a_250109.pdf which outlines a method of improved J4u as well as for JRMS. The 1.6T Taskforce embraced the JRMS change, but J4U required additional technical feasibility. This contribution address several comments against the stability of J4u03 and offers a solid foundation for an improved methodology that is leverageable to the future.

Supporters/Collaborators (Version 1.1)

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Useful References:

IEEE P802.3dj: Physical layer jitter proposal to advance/close comments against present JRMS and J4u03 methodologies
Contribution: https://www.ieee802.org/3/dj/public/25_01/calvin_3dj_01b_2501.pdf

IEEE P802.3dj 01/09/2025: Gines_Phase Only Jitter
Contribution: https://www.ieee802.org/3/dj/public/adhoc/optics/0125_OPTX/gines_3dj_optx_01a_250109.pdf

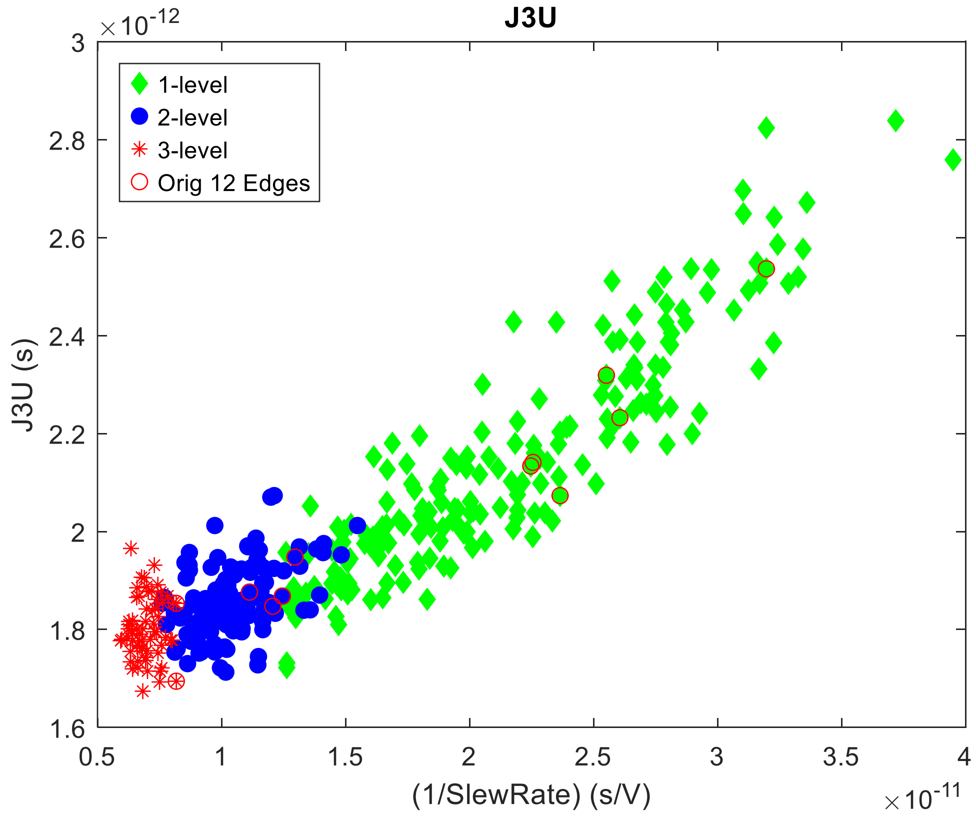
IEEE P802.3dj 07/15/2024:Calvin_1.6Tbps JNu operations / high loss channels
Contribution: https://www.ieee802.org/3/dj/public/24_07/calvin_3dj_01b_2407.pdf

G. Soliman, "The Accuracy of the Gaussian Tail and Dual Dirac Model in Jitter Histogram and Probability Density Functions," in IEEE Transactions on Electromagnetic Compatibility, vol. 64, no. 6, pp. 2207-2217, Dec. 2022, doi: 10.1109/TEMC.2022.3187081. keywords: {Tail;Jitter;Behavioral sciences;Standards;Computational modeling;Probability distribution;Probability density function;Deterministic jitter (DJ);dual Dirac;jitter distribution;random jitter (RJ);total jitter (TJ)}, https://ieeexplore.ieee.org/document/9830602

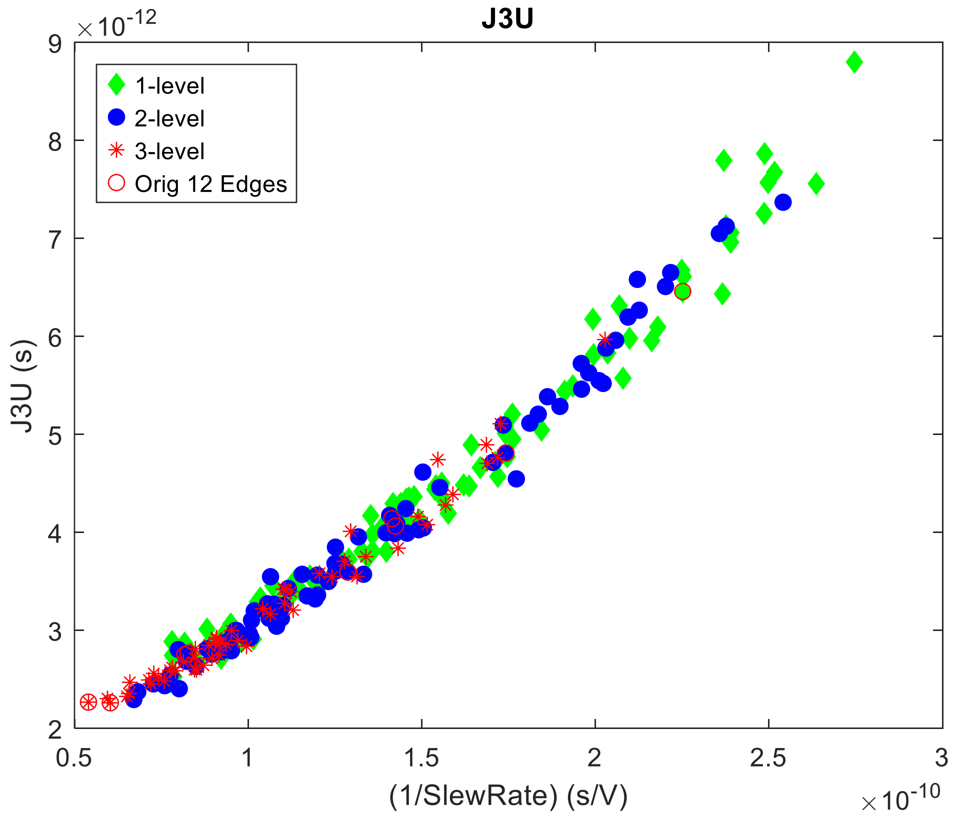
JNU

JNU is affected by the channel

JNU is affected by the channel which affects noise and slew rate. The behavior is similar to Jrms. JNU increases and becomes more variable with increased channel loss. (note the different scales in the two plots).



No Channel



31 dB Channel

Jitter Model

JNU using dual-Dirac model

The dual-dirac model can be used to find the horizontal (phase-only) measurement of JNU. Note that dual-dirac is typically used to extrapolate jitter to lower BERs, but here we use it only to model the histogram shape. The model is:

$$JNU = DJ_{dd} + 2 * Q * RJ_{rms}$$

The idea is to estimate horizontal components DJH_{dd} and RJH_{rms}. We can then approximate,

$$JNUH = DJH_{dd} + 2 * Q * RJH_{rms}$$

Define DJdd as the simple sum of horizontal and vertical, leading to a linear model:

$$DJ_{dd} = DJH_{dd} + DJV_{dd}$$

$$DJ_{dd} = DJH_{dd} + \left(\frac{1}{SR}\right) Ndd$$

RJrms is an RMS value, so it has the same model as Jrms:

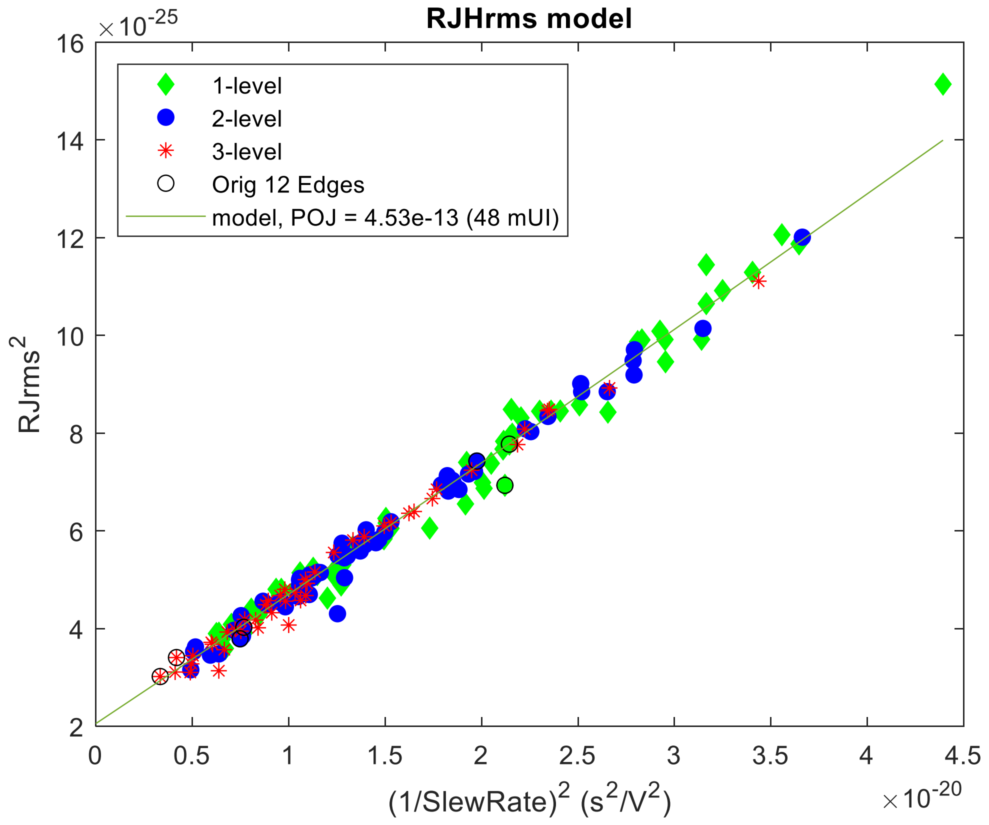
$$RJ_{rms}^2 = RJH_{rms}^2 + RJV_{rms}^2$$

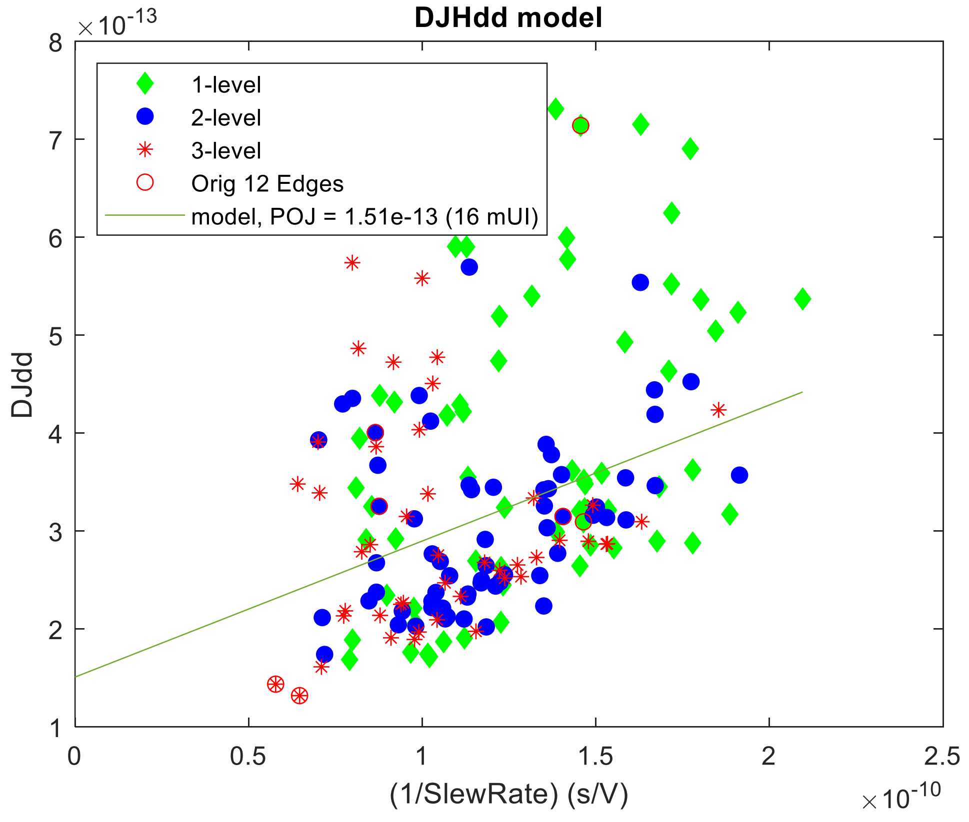
$$RJ_{rms}^2 = RJH_{rms}^2 + \left(\frac{1}{SR}\right)^2 N_{rms}^2$$

Jitter Model

Dual Dirac approach

Example dataset generated using a BERT, 106.25 GBd, PRBS9Q, 50 mUI RJrms, 50 mUI PJpp, Channel 31dB ISI. In the legends, POJ refers to the phase-only-jitter component, such as RJHrms on the left and DJHdd on the right.





Jitter Model

Some challenges

- Jitter decomposition must be done on each edge, which is an additional source of variability when compared to Jrms, which is a simple standard deviation.
- DJdd is not a physical parameter, it is a model parameter, so the POJ model for DJdd is only approximate. But its contribution to JNU is small.
- RJrms uses the same model as Jrms. However, in the dual-dirac model it is multiplied by 2*Q, so additive errors are also amplified by this same amount. In other words, RJrms is likely to be the more important parameter.
- Nevertheless, results are promising.

Jitter Model

Results

Here are modeled results using a Host-Low (HL/12dB) channel with different impairments. The true and estimated values of JNU are circled. Note that NrmsIn is the RMS value of added vertical noise (V).

All values in mUI

Input Params			True Horizontal Params			Orig DJdd		
RJrmsIn	PJ Amplitude	NrmsIn	RJrms	PJpp	J3U	RJrmsH	DJddH	JH3UH
0	0	0	0	0	3	1	0	4
50	0	0	50	0	330	48	21	335
0	50	0	0	100	101	0	103	103
0	0	50	0	0	0	3	4	24
50	50	0	50	100	386	55	42	404
50	0	50	50	0	330	49	20	339
0	50	50	0	100	100	0	94	94
50	50	50	50	100	386	54	46	400

Lab Instrument based test results

JH3U

- These results are for live data, PRBS9Q. JNU03 is included for comparison. With no channel, both JH3U and JNU03 are reasonably accurate. However, as the channel gets longer, JNU03 grows because it includes noise-to-jitter conversion, while JH3U does not (note that the last set of data has different impairments).
- The true values were estimated through modeling, by creating an ideal Gaussian histogram for RJ, an ideal histogram for PJ (sinusoidal jitter), convolving the two, and measuring J3U.

Latest JHNU results: 106.25 GBd, PRBS9Q, BERT

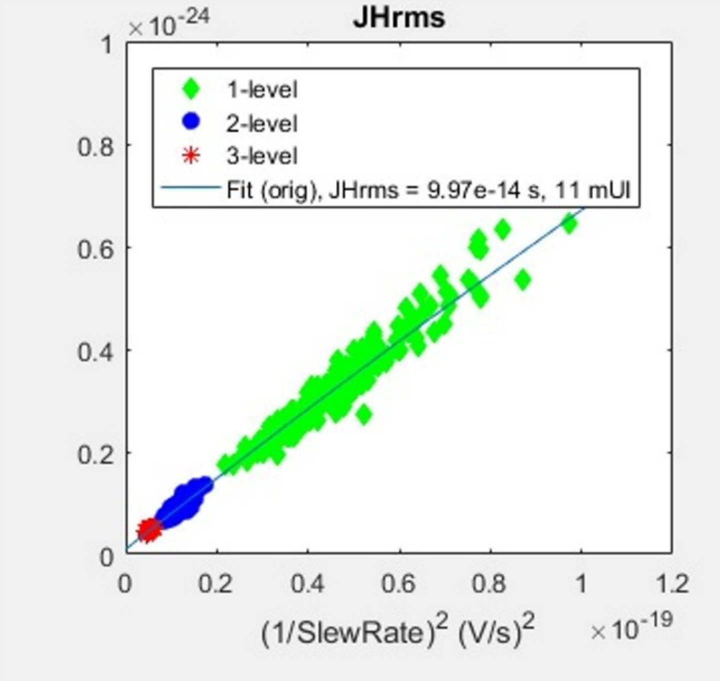
Channel	RJrms True	PJpp True	JH3U True	JH3U	JNU 03
0 dB	0	0	0	22	51
0 dB	30	0	198	192	188
0 dB	0	50	50	85	87
0 dB	30	50	223	218	219
12 dB	0	0	0	25	56
12 dB	30	0	197	193	202
12 dB	0	50	50	57	90
12 dB	30	50	222	219	232
31 dB	0	0	0	49	150
31 dB	30	0	198	190	241
31 dB	0	50	50	104	184
31 dB	30	50	223	230	368
31 dB	0	0	0	42	123
31 dB	50	0	330	317	331
31 dB	0	50	50	97	151
31 dB	50	50	347	333	394

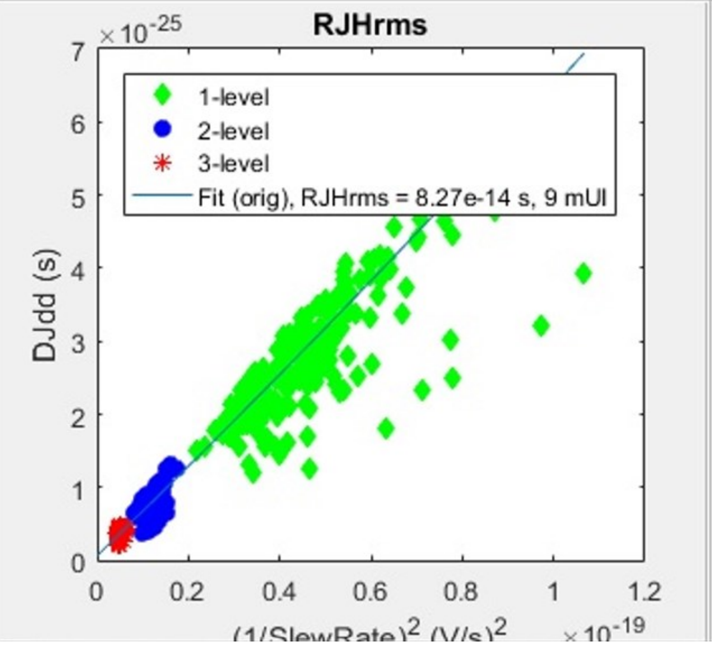
Field deployed JH4U beta-tool results.

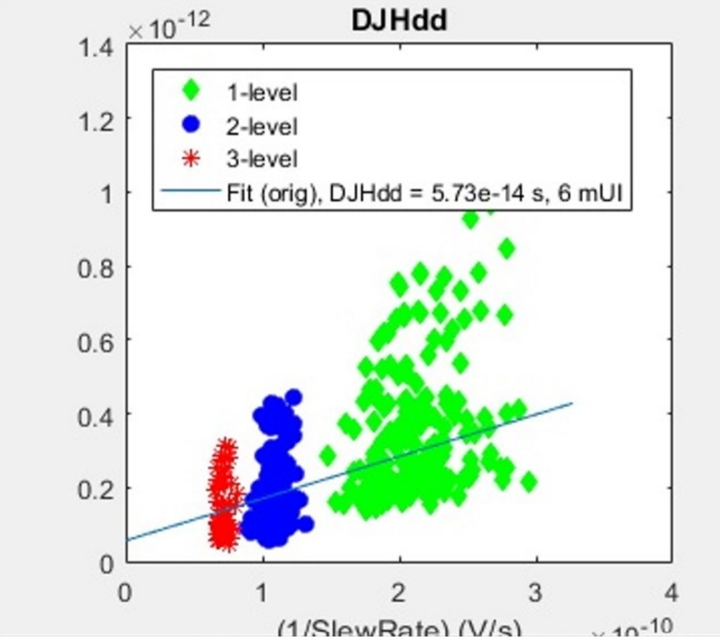
Anyone interested in access should contact: John.calvin@keysight.com

Run

	seconds	mUI
JHrms	9.9698e-14	11
RJHrms	8.2740e-14	9
DJHdd	5.7341e-14	6
JH3U	6.0186e-13	64
JH4U	7.0116e-13	74



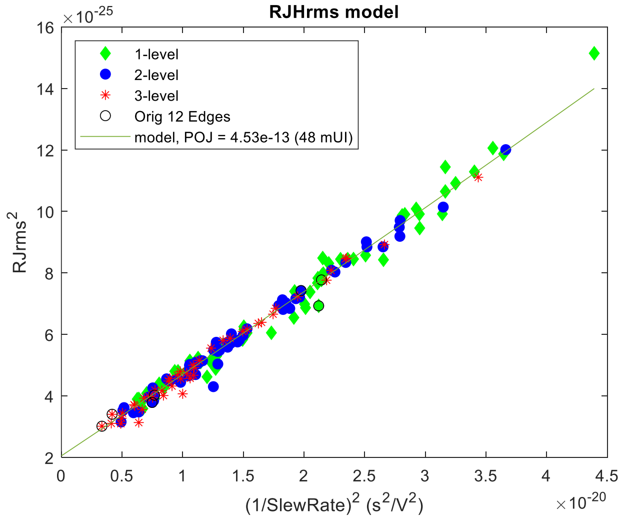


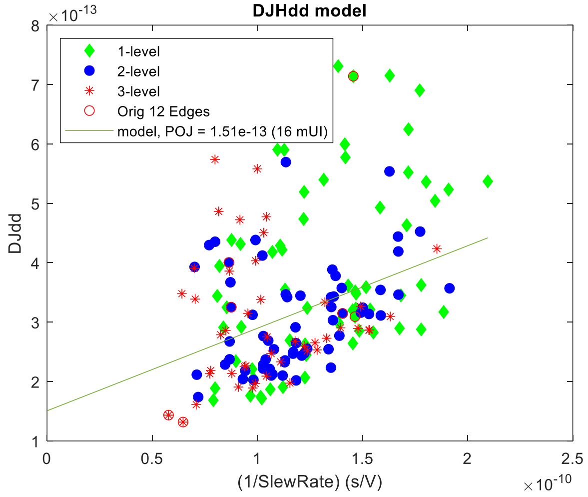


Jitter Model

Conclusions

- This contribution outlines a dual Dirac method of Total Jitter determination (J4u) using an extension of the phase-only jitter concept used currently in Jrms but now for JH4U.





- This contribution proposes a new model for JHNU (Phase only jitter version of JNU)
- Early test results show favorable potential of the model in preserving jitter measurement integrity after 30+dB channel losses.
- Field evaluations show real-world 1.6T hosts change failing J4U03 results to passing JH4U results as evaluated at TP1a.
- The Dual Dirac model is described in the reference: G. Soliman, "The Accuracy of the Gaussian Tail and Dual Dirac Model in Jitter Histogram and Probability Density Function” IEEE Transactions on Electromagnetic Compatibility, Volume: 64, Issue: 6, December 2022.

Proposed revision to Clause 179.9.4.6.2 J4u03

Calculation of the jitter parameter J4U uses the timing of multiple transitions in the pattern to estimate the jitter caused by clock phase noise while minimizing the effect of additive noise, using the method described in this subclause.

Select a set A of transitions from the test pattern used in the test. The size of this set should be large enough to enable calculation of J4U (as defined below) with sufficient accuracy. The set A should include multiple transition types between different PAM4 levels.

For each specific transition :

— Obtain a set Ai = {ti(1), ti(2), …} of transition times modulo the period of the pattern. The size of this set should be large enough to enable estimating JNU with sufficient accuracy. The set may be filtered by eliminating edges heavily affected by ISI.

— estimate the mean μi from the measured dataset Ai ..

— Estimate the random jitter RJrms_i and deterministic jitter DJdd_i from the measured dataset Ai using a dual-dirac jitter decomposition.

— Measure the slope of the signal at time μi, denoted si.

From the collections of RJrms_i and si, calculate the best-fit coefficients for the polynomial in 1 / si^2 defined by

RJrms_i^2 = a + b/si^2 + c/si^4

The coefficient a is the extrapolation of the measured data to an infinite slope. RJHrms is defined as the square root of a.

From the collections of DJdd_i and si, calculate the best-fit coefficients for the polynomial in 1 / si defined by

DJdd_i = a + b/si

Proposed revision to Clause 179.9.4.6.2 J4u03

The coefficient a is the extrapolation of the measured data to an infinite slope. DJHdd is defined as a.

Using RJHrms and DJHdd estimate the value of J4U as

J4U = DJHdd + 2*Q*RJHrms,   Where Q = 3.891.