# 802.3bj D2.1 Transmitter output jitter specification for NRZ PMDs

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# Summary

- We point out certain problems in the way D2.1 specifies following jitter values:
  Effective deterministic jitter excluding data dependent jitter, Effective random jitter, and Total jitter excluding data dependent jitter
- And we propose a practical methodology for these measurements
- If acceptable we would like to propose this methodology for both Clause 92 and Clause 93.
- We propose to not measure TJ on PRBS31 pattern

What does this proposal not do:

- We do not change the jitter budget
- We do not change the way Even-Odd jitter is measured

# Supporters

| | |
|---|---|
| Greg LeCheminant | Agilent |
| Matt Brown | Applied Micro Devices |
| Shannon Sawyer | Avago Technologies |
| Yasuo Hidaka | Fujitsu |
| Adee Ran, Kent Lusted | Intel |
| Maria Agoston | Tektronix |

# Problems with D2.1
# **92.8.3.9 Transmitter output jitter**

1. It is really difficult to actually measure jitter to BER of $10^{-9}$, let alone $10^{-12}$ at 25 Gb/s with sufficient resolution.
   There is a strong implication that J9 is measured and no statement that TJ at BER=$10^{-12}$ can be estimated.
2. The transmitter will always be used in a system with FEC which can convert BER=$10^{-5}$ to BER=$10^{-18}$. No need for TJ spec beyond $10^{-5}$ or anything beyond J6 for interpolation.

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# Problems with D2.1
# **92.8.3.9 Transmitter output jitter**

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3. Calculations of
   “Effective deterministic jitter excluding data dependent jitter” involve a direct subtractions of physical measurement on one pattern (DDJ, on PRBS9) with Dual-Dirac model of jitter (effective DJ) on a different pattern (PRBS31 or Scrambled Idles); there’s little physical validity in subtraction of different measures.
   (See attachment A for more detail).

   This point was confirmed in experiments by Charles Moore (presentation to the jitter ad-hoc titled “Transmitter output jitter specification in IEEE802.3bj for NRZ PMDs”; see Attachment B.

# Proposed Specification change for **92.8.3.9 Transmitter output jitter**

Relevant to “Table 92–6—Transmitter characteristics at TP2 summary”:

1. Keep even-odd jitter spec the same.
2. Change the measurement method of the following:
   1. Effective deterministic jitter excluding data dependent jitter
   2. Effective random jitter
   3. Total jitter excluding data dependent jitter (if this is needed)

   The measurement method and algorithm are given starting on next page.

3. DDJ in D2.1 is only used to calculate other values, and that in a way we found to be not valid. Thus we find that DDJ is not specified in D2.1. We recommend removing DDJ.
4. TJ@BER $10^{-12}$ can not measured in the way described. See attachment B. We propose to remove TJ from the specification.
5. Keep “The effect of a single-pole high-pass filter with a 3 dB frequency of 10 MHz is applied to the jitter” for all jitter.

# New Measurement method

- In following slides is a verbal description of the measurement and extrapolation process.
- A pictorial description follows.

# Key constraints, assumptions and limitations

- Only a simple dual Dirac jitter separation is recommended here.
- The key step of our analysis is to use the dual Dirac on just one positive and one negative edge. This removes the DDJ from the measured distribution, thus making the separation of remaining components more robust. Measurement on either edge shall meet the limits ~~given in~~ based on D2.1, as follows:
  - BUJdd: 0.1 UI (NRZ – Cl. 92, 93); compare to CDJ: 0.05 UIpkpk (Cl. 94)
  - $RJdd_{RMS}$: 0.01 UI (NRZ – Cl. 92, 93); compare to CRJrms: 0.005 (Cl. 94)
- A key assumption is that the jitter distribution is the same on all positive or negative edges. This is typically true for low signal-path ISI signals, practically for signals when the eye at least half-open.
  For signals with large ISI and slow slew rates the noise on edge translates into more jitter on slow edges than on fast edges. Handling of such signals (closed eye due to signal-path ISI) would increase the complexity of this measurement, and add the undesirable sensitivity to instrument differences (e.g. the oscilloscope noise floor).

# New Measurement method for jitters excluding Data Dependent Jitter, page 1

- The methodology for measuring “Effective deterministic jitter excluding data dependent jitter”, “Effective random jitter”, and “Total jitter excluding data dependent jitter” is as follows:
- Use a PRBS9 pattern. The transitions within sequences of five zeros and four ones, and nine ones and five zeros, respectively, are used for histogram acquisition. These are bits 10 to 18 and 1 to 14, respectively, where bits 1 to 9 are the run of nine ones.
  Note: This are the transitions used to measure the transition time in “CEI-28G-VSR D9.”.



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# New Measurement method for jitters excluding Data Dependent Jitter, page 2

- Acquire the horizontal histogram of a transition. Acquisition conditions are:
  - histogram resolution shall be no coarser than 50 fs/bin but no finer than 5 fs/bin
  - There are at least 20,000 samples in the histogram.
  - Vertical size of the histogram box shall be no more than 1 % of the VMA of the signal. Note: on a 10 division, 400 bins of vertical resolution oscilloscope screen with signal’s VMA over 5 divisions each vertical bin is 2% of the signal’s VMA.
  - The histogram shall be at zero crossing

# New Measurement method for jitters excluding Data Dependent Jitter, page 3

- Space two copies of the histogram at 1 UI from mean to mean.
- Develop a CDF in the Q-space (a bathtub). On each side of the bathtub select horizontal bin with the highest Q value and at least 50 histogram hits at that time position. Starting with this bin select adjacent consecutive 4 bins with lower Q for a collection of 5 bins, again on each side.
  Fit a straight line (still in Q-space) through this collection of 5 bins on each side of the Q bathtub.
- Develop a dual Dirac model from the straight-line fits as follows:

find an LMS fit to the 5 bins of the form

Ql= mjl*jitter + bjl     for the left hand side of the bath tub

Qr= mjr*jitter + bjr     for the right hand side of the bath tub

RJdd = 2/(mjr-mjl)

DJdd = mjl/bjl - mjr/bjr

# New Measurement method for jitters excluding Data Dependent Jitter, page 4

Note that in our context of a single-edge analysis the resulting value of DJdd has the meaning of uncorrelated bound jitter; the value of RJdd has the meaning of uncorrelated unbound jitter.

The resulting dual Dirac model results are then used as follows:

- The found DJdd is used as
  "Effective deterministic jitter excluding data dependent jitter"
- The dual Dirac model RJdd is used as "Effective random jitter"
- The dual Dirac model's TJ@BER is used as "Total jitter excluding data dependent jitter"; ditto for the jitter values at the J5 and J9 levels if this is needed.


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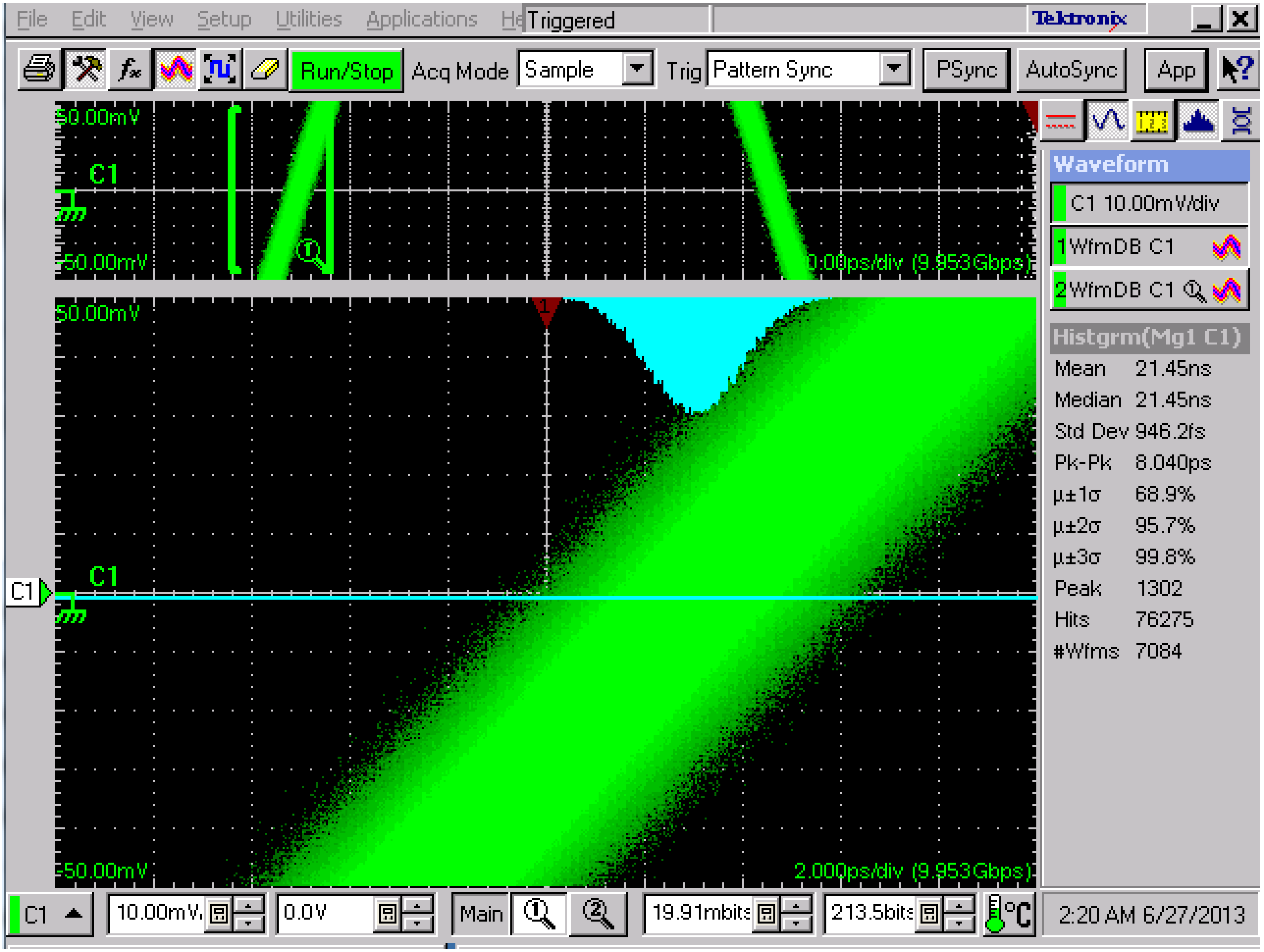
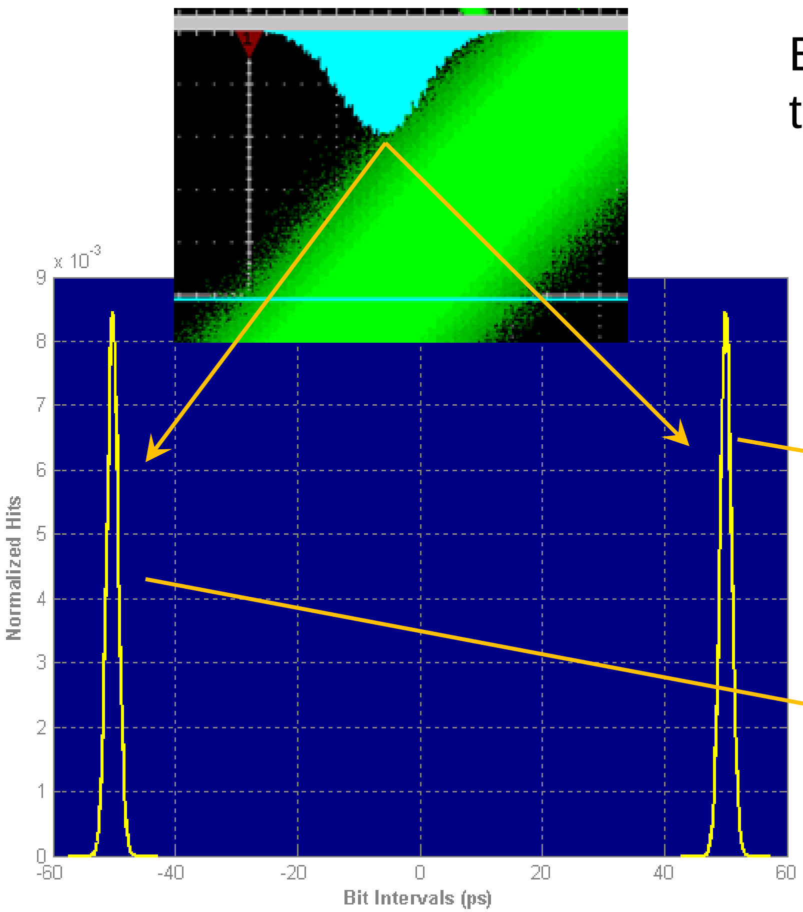
# Examples of data processing in the new method

- Pattern (top window) and the selected edge with histogram (lower window)

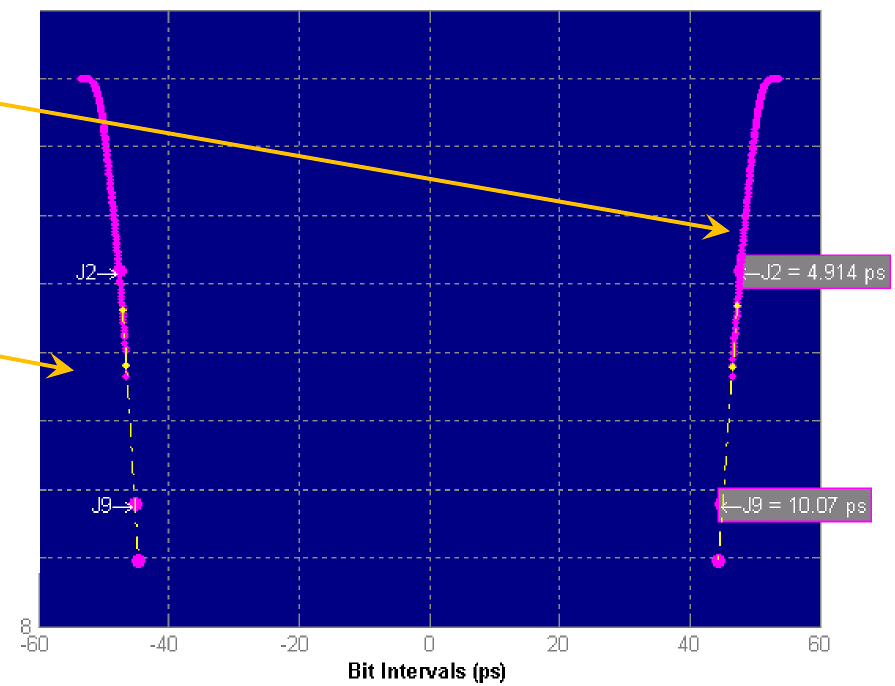


# Example of a histogram to CDF calculation

- The histogram to CDF calculation




Each histogram (on the left) is a copy of the acquired histogram.



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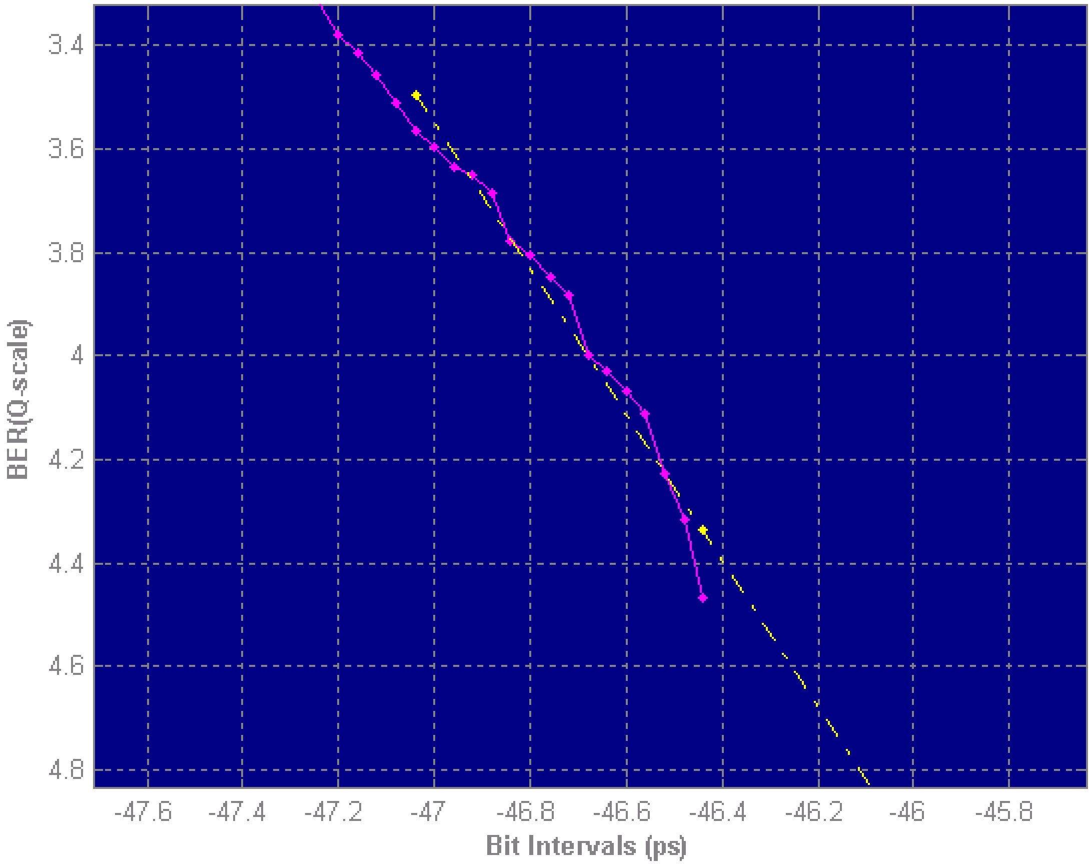
# Detail from the example of a CDF fit to

- Acquired data, in bins: purple dots
- Yellow: linear fit.

The fit points in this example are:
the leftmost point: point in the horizontal bin corresponding to the leftmost point on the yellow fit line;
And adjacent consecutive bins to the right for a total of 5 bins.





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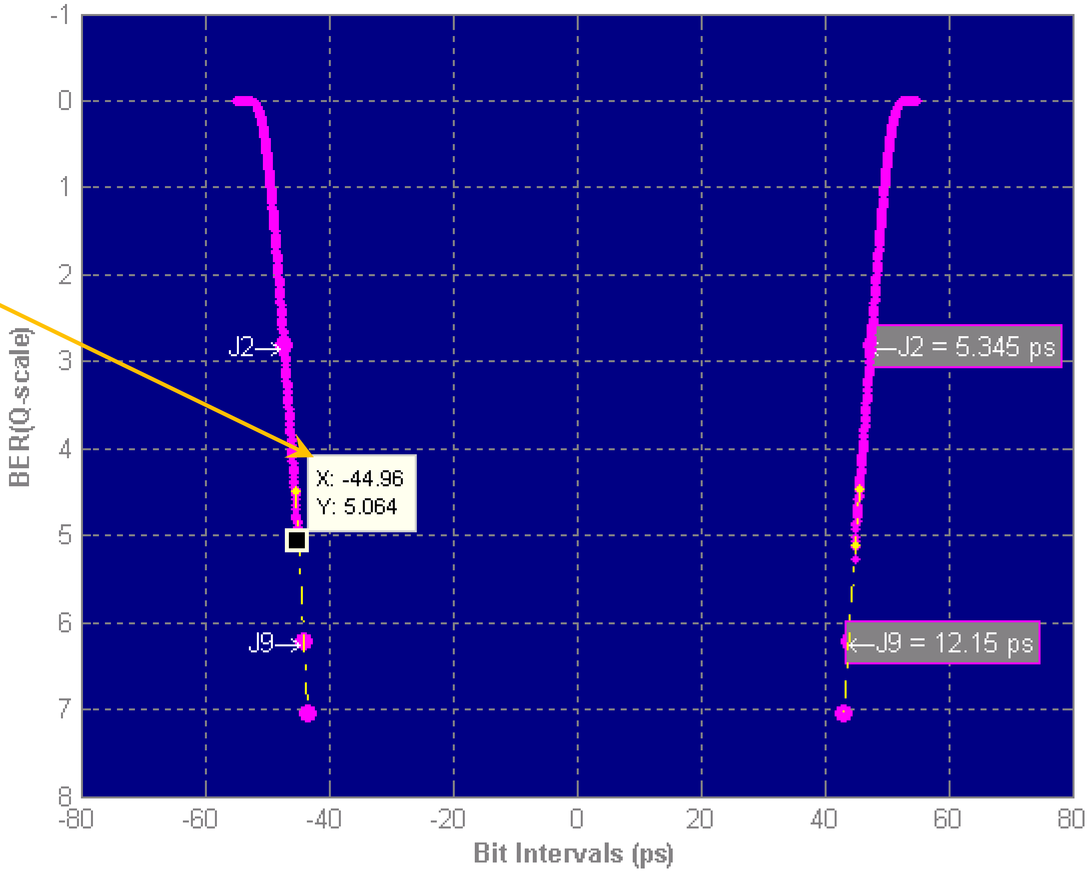
# Example of a lengthy acquisition yields J5 measurement

- Example of a long acquisition (10s of mins) capturing to below J5 level
- Long acquisition as this can be used to verify the J5 level; lower levels of bathtub are prohibitively time-consuming.
- Theirs is no suggestion that this level of date needs to be acquired for normal test.



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# Discussion of problems and perceived problems 1

- New definition doesn't measure with PRBS31 or other long pattern.
  A1: neither does anything else at 25 Gb/s; BERT's jitter floor is too high, oscilloscopes never acquire a statistically significant number of PRBS31 patterns.
  A2: PRBS15 *can* be fully measured at 25 Gb/s with available instruments, that might be acceptable from the measurement point of view… it is not clear that all existing chips support this length; and there will be a penalty from the time-processing point..
- New definition doesn't properly handles NP-BUJ (non-periodic bounded uncorrelated jitter)
  A: The high probability NP-BUJ is correctly binned into the deterministic part of the Dual Dirac model. The low probability will recognized only if the data acquired reaches the end of the NP-BUJ distribution. This is a small pessimism. Acquiring more data improves this accuracy.
- New definition is not a direct match to the OIF CEI jitter methodology
  A: OIF doesn't full explain the algorithms.

# Discussion of problems and perceived problems 2

- Errors due to growth of RJ for longer patterns
  This effect is small and poorly understood; currently no good methodology exists.

# Comments, discussion

- Thank you

# Attachment A

Currently we spec effective deterministic jitter excluding data dependent jitter as follows:

“Effective deterministic jitter excluding data dependent jitter is the difference between effective DJ and DDJ

(see 92.8.3.9.3) and shall be less than or equal to 0.15 UI regardless of the transmit equalization setting.” (D2.1, pg. 202, line 53 - 54).

Where DDJ is directly measured on PRBS9 as a peak-peak value of time interval error.

Where effective DJ is derived from J5 and J9 measured on a e.g. PRBS31 pattern. J5 and J9 are bathtub closure jitter, to wit: “If measured by plotting BER vs. decision time, it is the time interval between the two points with a BER of 10–*n* /4. Measure two values: J9 and J5”. (Pg 202, line 47, 48) and are used to develop a dual-Dirac deterministic model, our effective DJ.

The subtraction “difference between effective DJ and DDJ” is physically invalid since the DJ is a dual Dirac, and the DDJ is Peak-Peak.

Beyond that, since in general DJdd <= DJpkpk, the subtraction can yield results that are either positive or negative.

- For good discussion of the problem see “What the Dual-Dirac Model is and What it is Not” by Ransom Stevens in the “Jitter 360° Knowledge Series”, editor Pavel Zivny.

# Attachment B

To illustrate problems with the current jitter spec we set up a simulation of a jitter measurement. The simulation model consisted of an ideal jitter free transmitter, a COM package model with trace length and capacitor values from table 93-9 and a host trace model, Quadra_8p25in_Pair8_9_THRU.s4p, provided to the task force by Megha Shanbhag of TE Connectivity, to represent the channel from TP0 to TP2. Various PRBS patterns were launched by the ideal transmitter and a jitter measurement was simulated at TP2.

Simulation were done:

1. With oversampling of 32
2. Rise time of 1 sample
3. No jitter from source
4. No equalization

The next slide shows Sdd21 for the the host trace and for the entire channel and the following slide a simulated PRBS9 eye at TP2.



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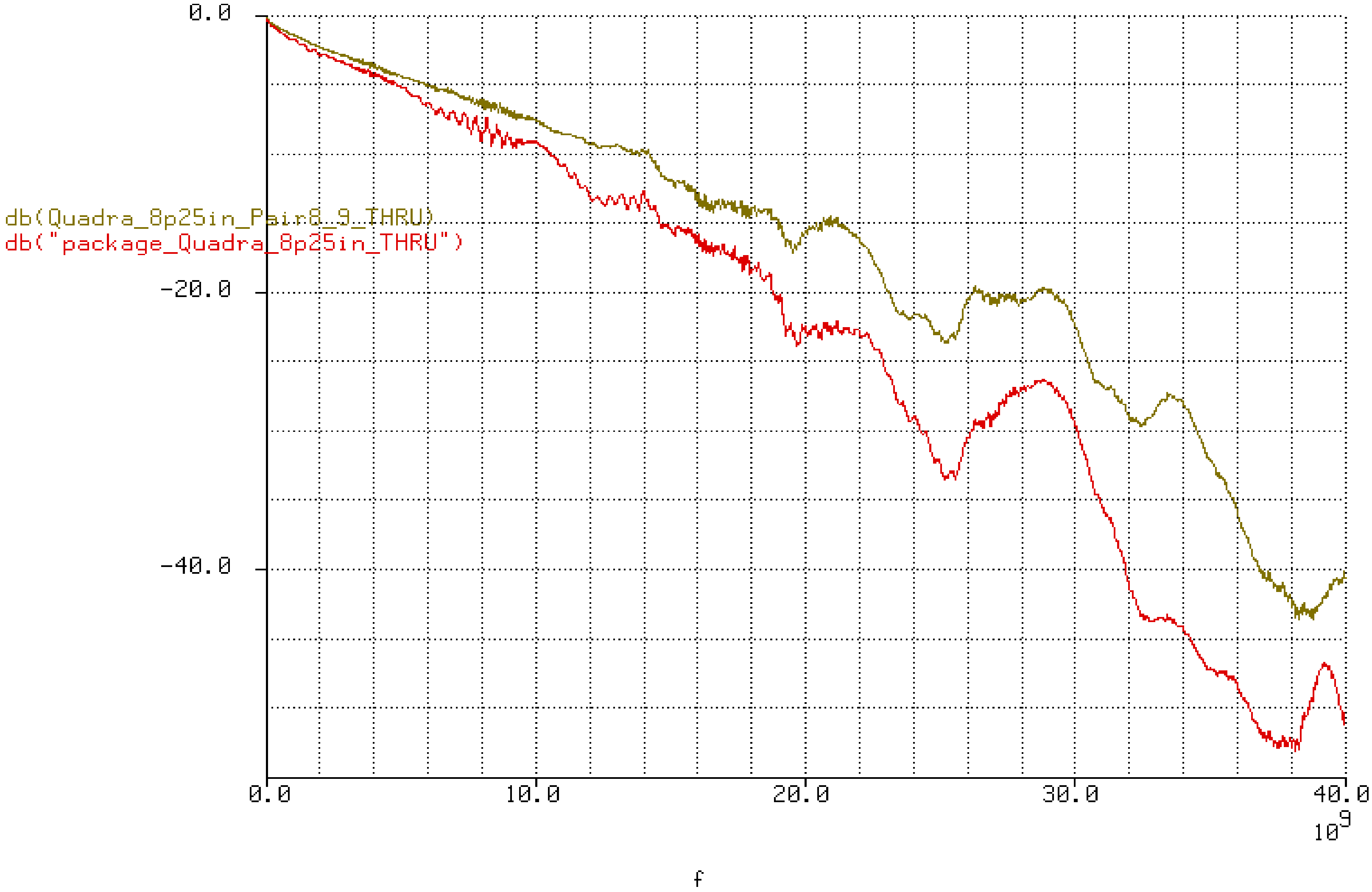
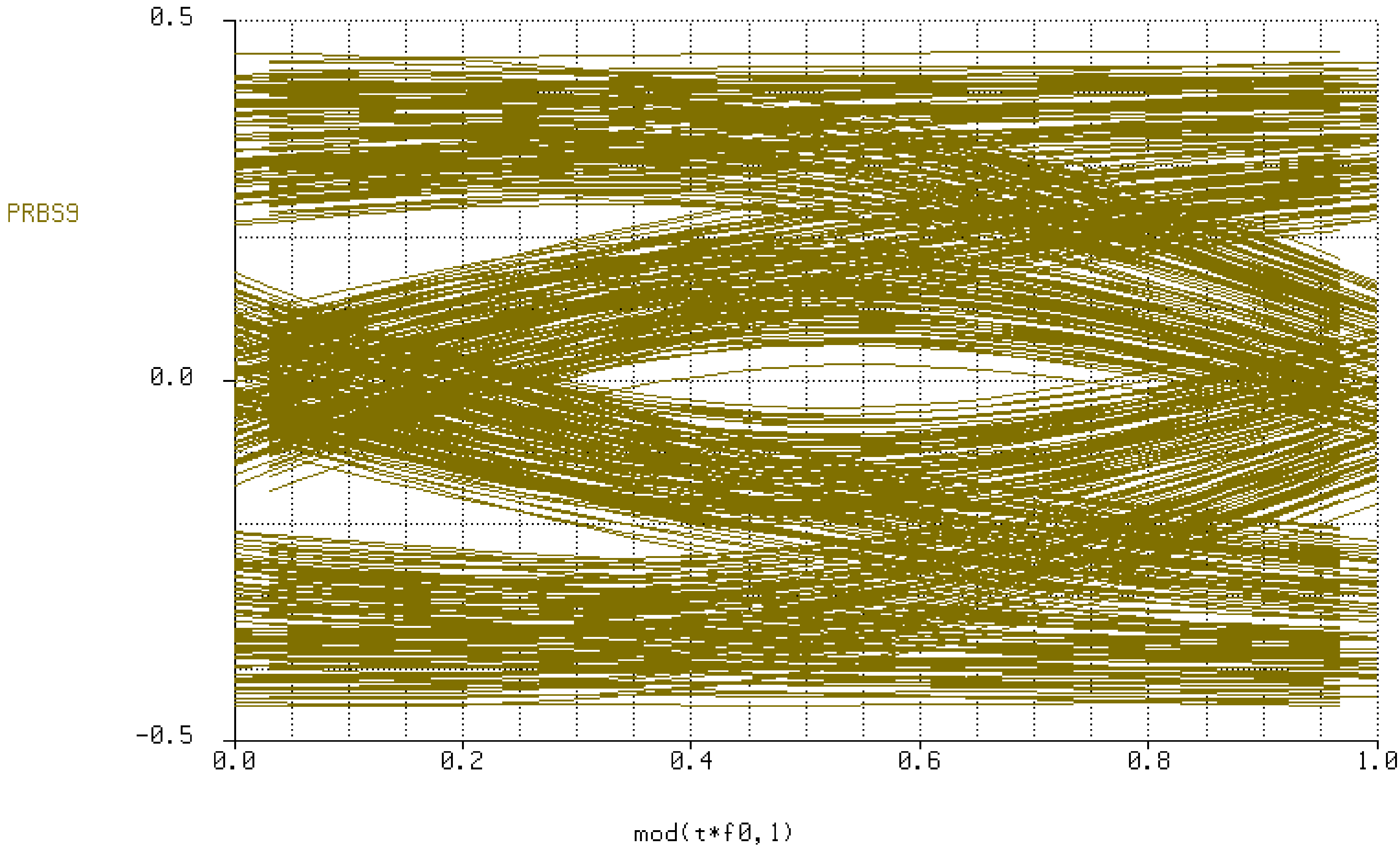



Host loss and host plus package loss

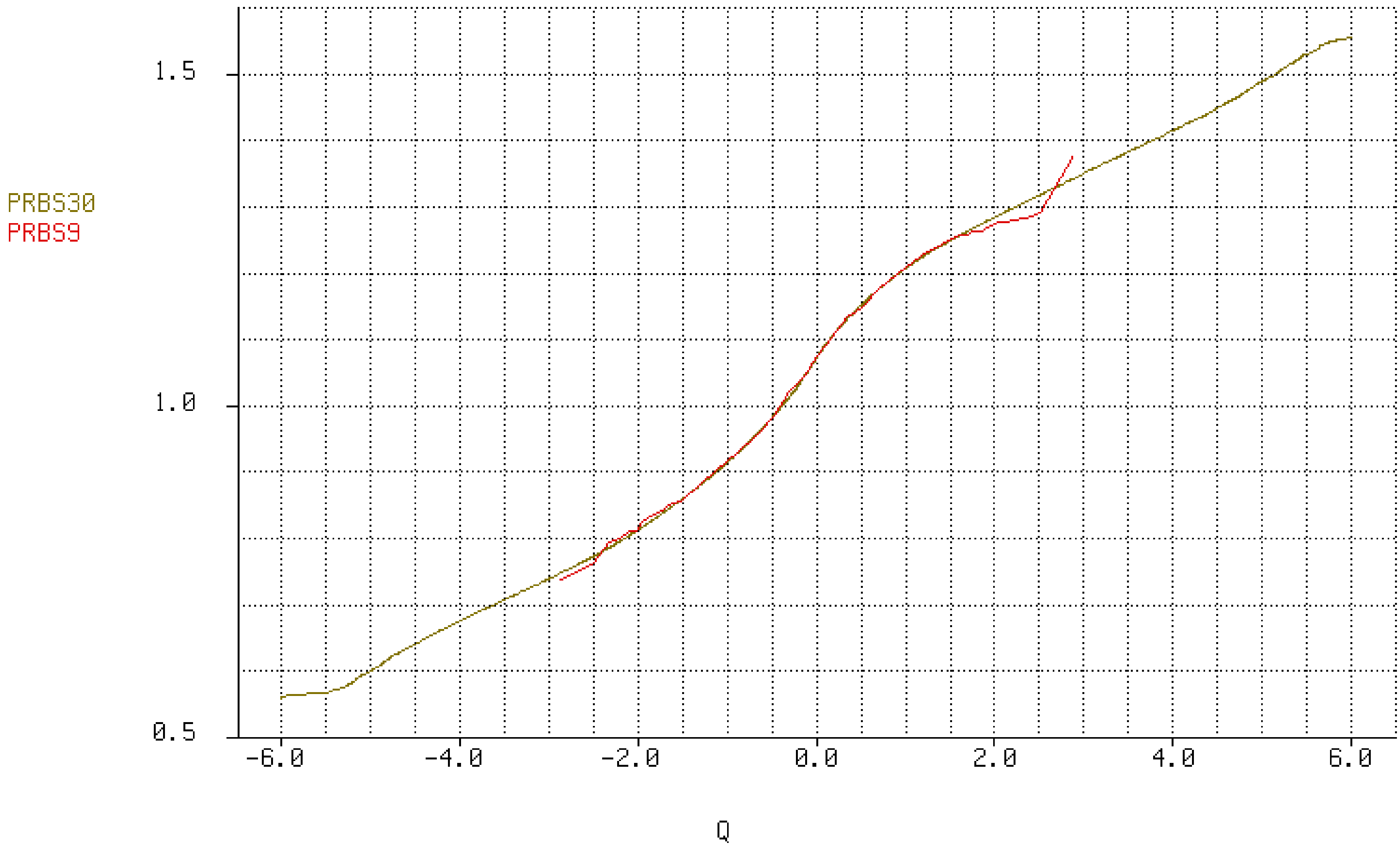
# PRBS9 EYE



The next slide shows a plot of jitter vs Q for a PRBS9 pattern and for a PRBS30 pattern.

Note this plot corresponds to the right hand edge of the eye plot and that the PRBS30 eye pattern would be closed.

# Jitter vs “Q” for PRBS30 and PRBS9 pattern



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We then applied various rules from the jitter spec in Clause 92.8.3.9 to the data represented by the above jitter vs Q plot to extract “Total jitter excluding data dependent jitter”, “Effective deterministic jitter excluding data dependent jitter”, and “effective random jitter”.

Jitter computations per 92.8.3.9. (continued).

Using data simulation plotted in the jitter vs Q plot.:

| | | |
|---|---|---|
| DDJ | = | 642 mUI |
| TJ (at $10^{-12}$ would actually be greater) | = | 1000 mUI |
| J9 | = | 993 mUI |
| J5 | = | 774 mUI |
| Total jitter excluding data dependent jitter | = | 358 mUI |
| DJ | = | 236 mUI |
| Effective deterministic jitter excluding data dependent jitter | = | -406 mUI |
| effective RJ | = | 764 mUI |

This gives:
effective RJ out of spec
TJ excluding data dependent jitter out of spec
Effective deterministic jitter excluding data dependent jitter in spec and negative

All for an ideal jitter free transmitter.