Jitter measurement and patterns for chip-to-chip 200GAUI-4 and 400GAUI-8

Piers Dawe

Mellanox

Introduction

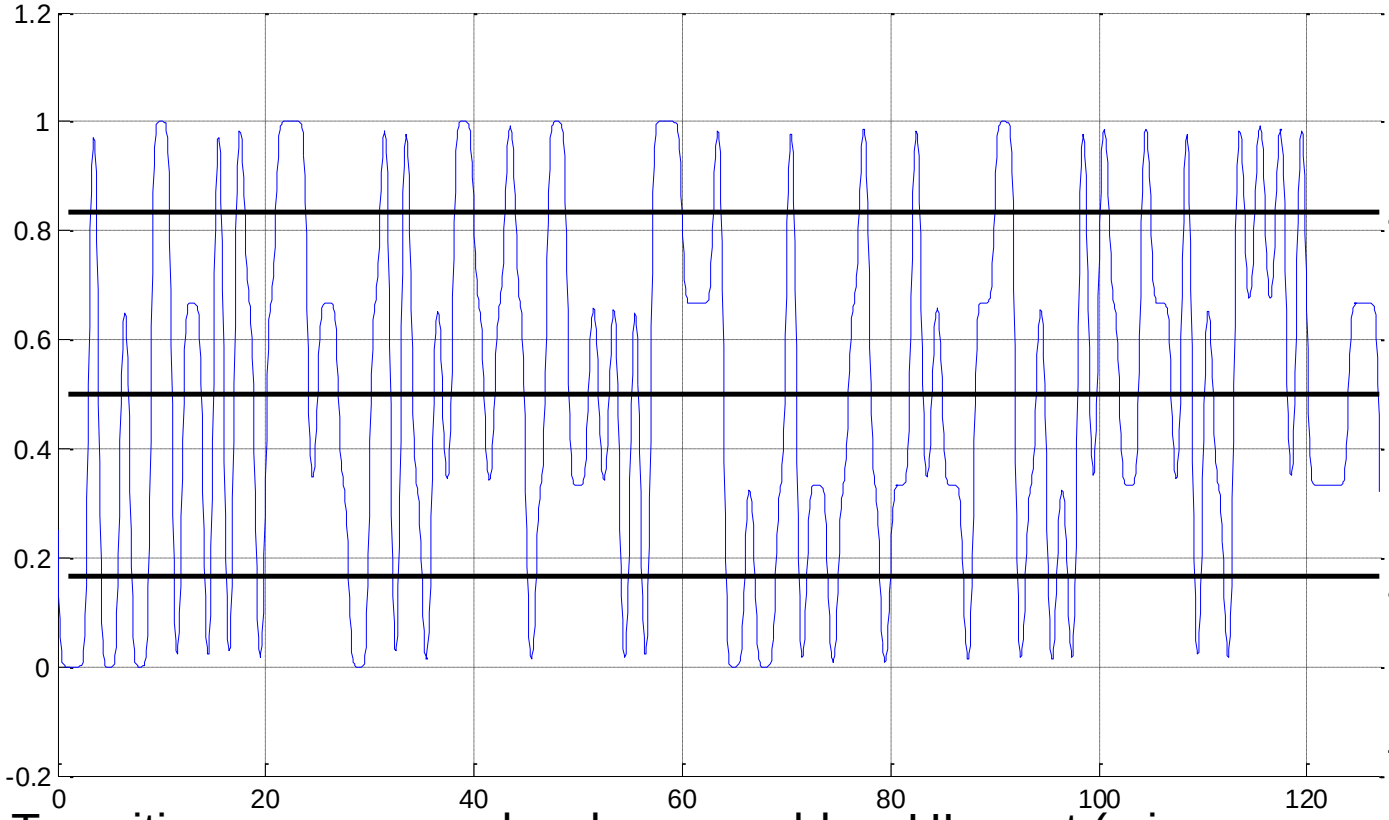
- The present draft measures Jrms and J5 on an 0303... pattern "JP03A" and measures even-odd jitter on an 0303... pattern with alternating phase "JP03B"
- These patterns are so unrealistic that one cannot expect a product to work normally with them, defeating the point of the measurement
- They don't exercise all the circuitry: same 2 transitions again and again missing the other 46 (?) possible transitions, no test coverage of the two middle levels.
- Would require extra circuitry to run a special pattern on one lane and realistic crosstalk aggressors (not these patterns) on the other lanes

- An additional slide addresses the relation between J4 and BER

Measuring jitter with a realistic pattern

- It was proposed that in PAM4, jitter can be measured by finding the timing statistics from all the transitions in a QPRBS13 pattern
- Advantage: measures jitter in a realistic situation
- We don't need many measurements of each transition to get enough statistics across all edges
- How does this work if the transmitter emphasis is significant?
- Can we use the same pattern on all lanes?
- Do we have a clear idea of what we want to measure anyway?

QPRBS7, no emphasis

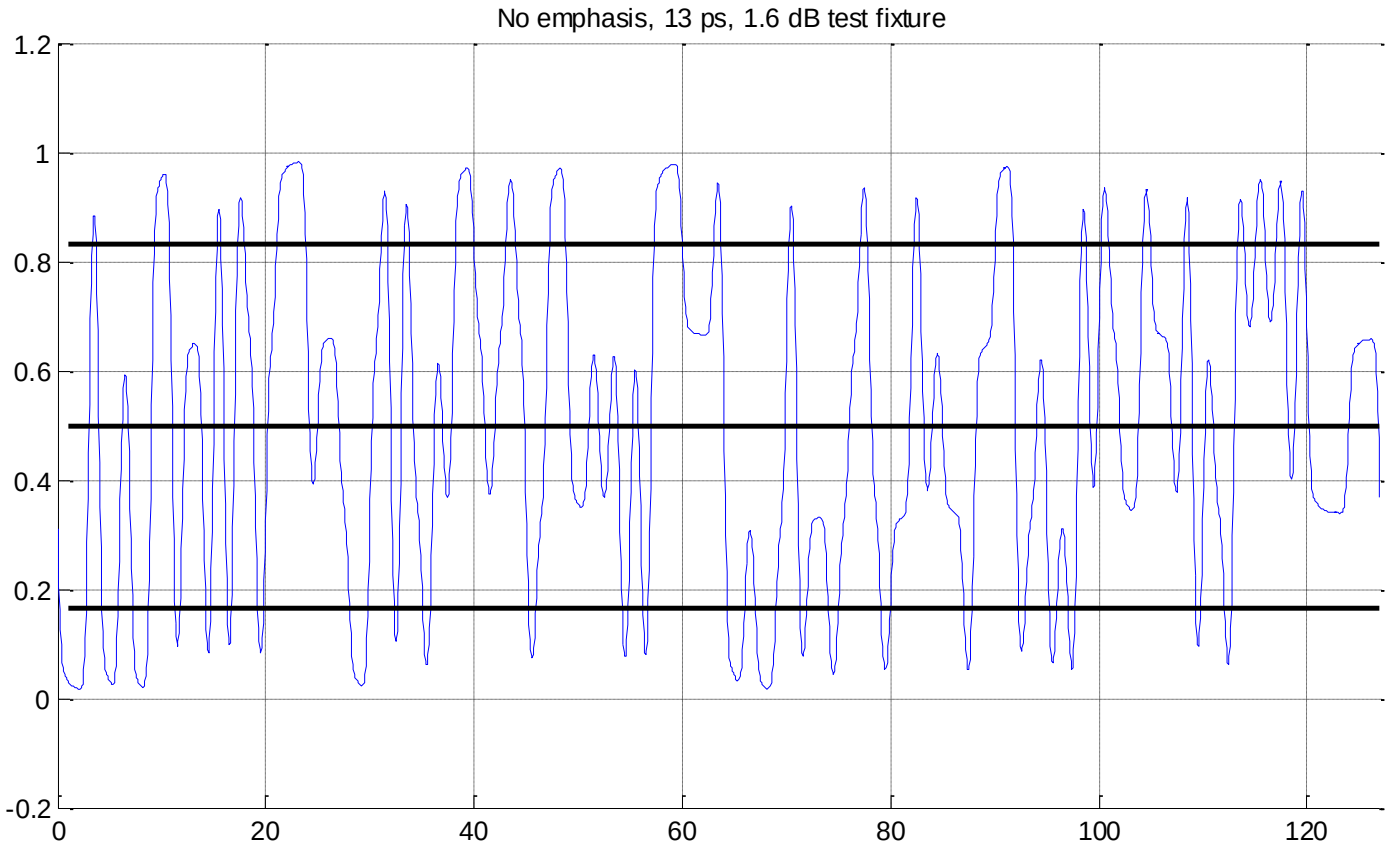


Transitions across any level are roughly n UI apart (n is an integer)

Separate enough to be measured

This will remain the case with small amounts of emphasis

QPRBS7, with test fixture loss



Transitions are all still present, distinct and measurable

QPRBS7, adding emphasis

All the transitions from the no-emphasis case remain, still well separated

3072

4096

3072

"permanent" edges in PRBS13Q

total 10240 in 8191 UI

Some additional transitions appear: can be ignored

Some borderline transitions appear: should be ignored

No transitions disappear

Instrument can know which are the "permanent" edges

Observations

- Method continues to work when emphasis is used
- For consistency, additional transitions should be excluded from the measurement
- The instrument can know where the "permanent" transitions are, in the same way that it knows what each symbol level is intended for calculating linearity

More detail

- In a simple algorithm, we define three slicing levels as shown
  - e.g. (-1+ES1)/2, ES=(ES1+ES2)/2, (ES2+1)/2 as defined by the linear fit method
- Then we collect histograms of crossing times for each place in the sequence where the signal crosses one of those three levels
  - Find the mean of each histogram, add them all together with means aligned
  - Needs >= 2e5 crossing time samples spread across the 10240 edges to get an estimate of J5 without extrapolation, or about 20 per edge
- So a bottom-to-top transition would be measured in 3 places – is this what we want?

Should we measure all the edges?

- Options include:
  - Measure all permanent edges, including measuring a bottom-to-top transition in 3 places
  - Or, measure each transition just once, with thresholds (-1+ES1)/2, ES1, ES=(ES1+ES2)/2, ES2, (ES2+1)/2 (roughly half way up each transition)
  - Or, measure the crossing times at the levels near the logical symbol levels before and after: so a bottom-to-top transition would be included twice, at (-1+ES1)/2 and (ES2+1)/2 – ignoring the timing at ES=(ES1+ES2)/2 because it's unlikely that the middle-level decision will be in error because of this transition
- The last way balances up the number of edges sampled at each level

If we need a different victim and aggressor patterns

- I expect that QPRBS7 contains all 64 possible 3-symbol sequences
  - Because PRBS7 contains all possible 6-bit sequences
- It would be a convenient test pattern for the victim if we need something that's not PRBS13Q
  - While aggressor lanes should use a longer pattern than QPRBS7, or mission-mode signal such as scrambled RF or scrambled idle

J4 for BER 1e-5

- The 4 means all but 1e-4 of the jitter distribution
- So 5e-5 each side (left and right), each level
- Transition density is 1/2 across middle level, 3/8 across others
- So the probability of an error at one level is 2.5e-5 or 1.875e-5
- Symbol error ratio is 2.5e-5+2*1.875e-5 = 6.25e-5
- The other bit in the PAM4 symbol is probably not in error, because of Gray coding
- So BER is 3.125e-5, half way between 1e-5 and 1e-4
- If we ignored the middle-level timing of bottom-to-top and top-to-bottom transitions, BER might be 2.8125e-5, nearer 1e-5
- We measure jitter before the channel with crosstalk and the receiver with noise so (unless the effect of transmitter noise and Gaussian jitter is larger than these) we should measure at a higher probability than the target BER for good correlation to overall link performance
- Measuring at a higher probability also provides more accurate and/or faster, cheaper measurements