Effect of observation bandwidth and filter profile

Piers Dawe

IPtronics

Supporters

Mike Dudek	QLogic
Ali Ghiasi	Broadcom
John Petrilla	Avago Technologies
Jonathan King	Finisar

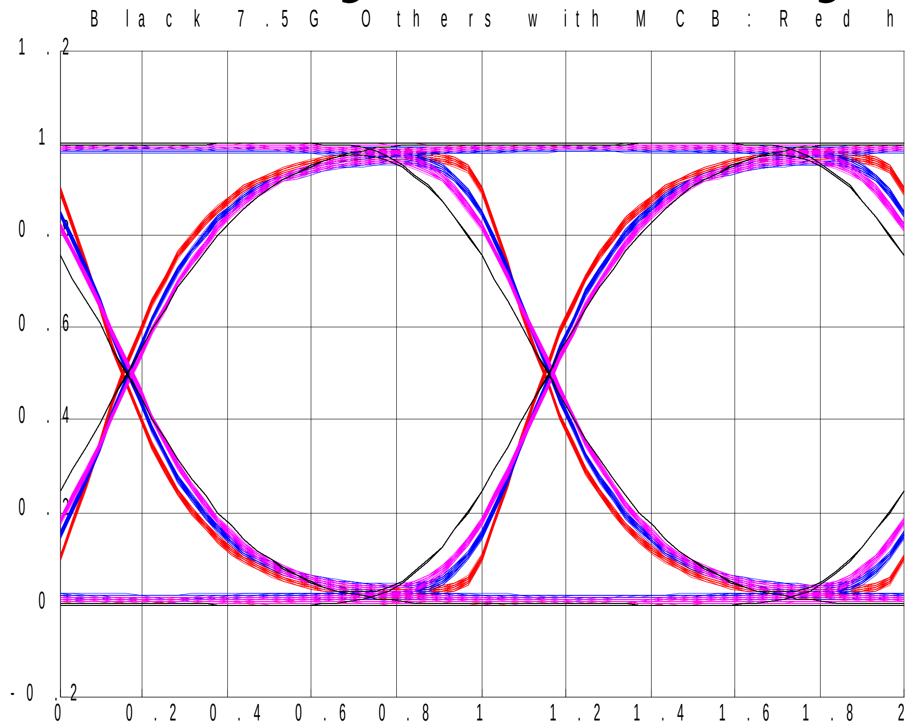
Introduction

1. What effect does the observation bandwidth have? (comments 37, 94)
   - Electrical observation bandwidth made of two parts: compliance board (test fixture) and instrument, e.g. oscilloscope
   - Compliance board response specified up to 10 or 11.1 GHz
   - Instrument bandwidth specified as 12 GHz, at least 18 GHz, at least 20 GHz, or unstated
   - Product receiver bandwidth assumed 7.5 GHz in ICN calculation
   - Minimum rise time, 24 ps at IC or connector, assumed
   - NRZ coding gives sin(f)/f spectrum
1. What effect does filter shape in stressed eye generator have? (comments 142, 103, 104)
   - Eye is specified by width (J2, sometimes J9) and height (VECP) but not shape
   - Filter response sometimes specified as fourth-order Bessel-Thomson (BT4)

Part 1, electrical eyes Simulation method

- Create clean NRZ eye
- Filter twice with first order filter
  - Similar to 85.10.7 ICN calculation, equation 85-28
  - Has more high frequency content than other likely filter profiles
  - Check that risetime is 24 ps
- Filter through ideal Annex 86A MCB (= Clause 85 cable test fixture)
  - Modelled with linear phase
- Compare eyes in 7.5*, 12, 18 GHz, and infinite bandwidth
  - BT4 filters
  - * 7.5 GHz without MCB, representing product receiver. This is the "target", most representative measurement, although product receivers could have more or less BW

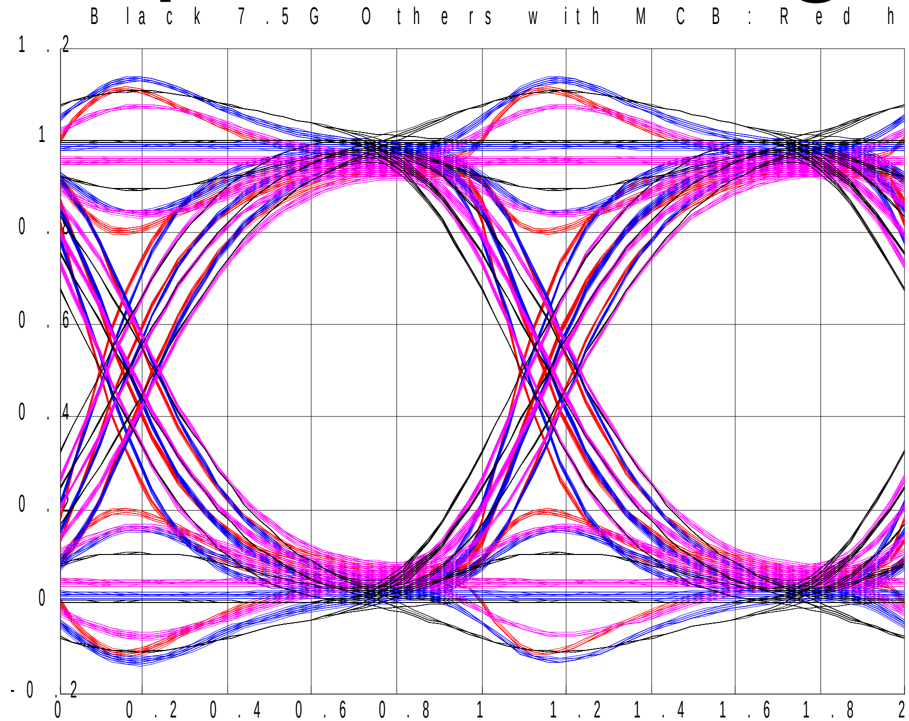
Clean eyes, everything ideal



Black	7.5 GHz BT4
Others with MCB:	
Red	High BW scope
Blue	18 GHz BT4
Magenta	12 GHz BT4

- Risetime of these fastest eyes is affected by bandwidth
  - Taken into account in specs, but see later
  - Signal that product receiver uses is slower than any of the measured eyes

Repeat with degradations



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Red	High BW scope
Blue	18 GHz BT4
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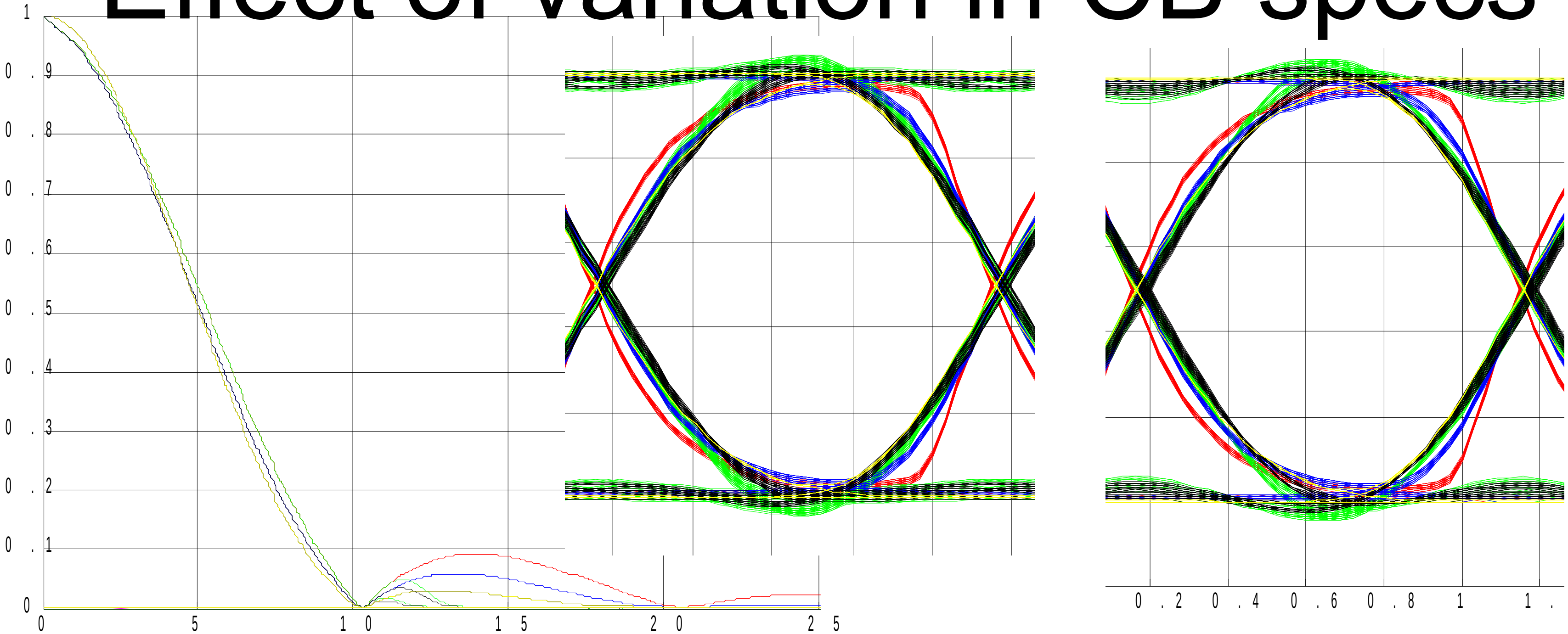
- Simulate crosstalk or reflections by copying signal, high pass filter, delay, and add back in
- Jitter is barely affected by scope bandwidth, *in this case*, because filtering affects both risetime of signal and amplitude of crosstalk or reflections

Three compliance boards

1. Frequency response extrapolated above specification frequency but per equation for *reference* MCB loss in draft
2. Per equation for reference MCB loss in draft but rolls off after 11.1 GHz
3. As above but rolls off after 10 GHz

Effect of variation in CB specs

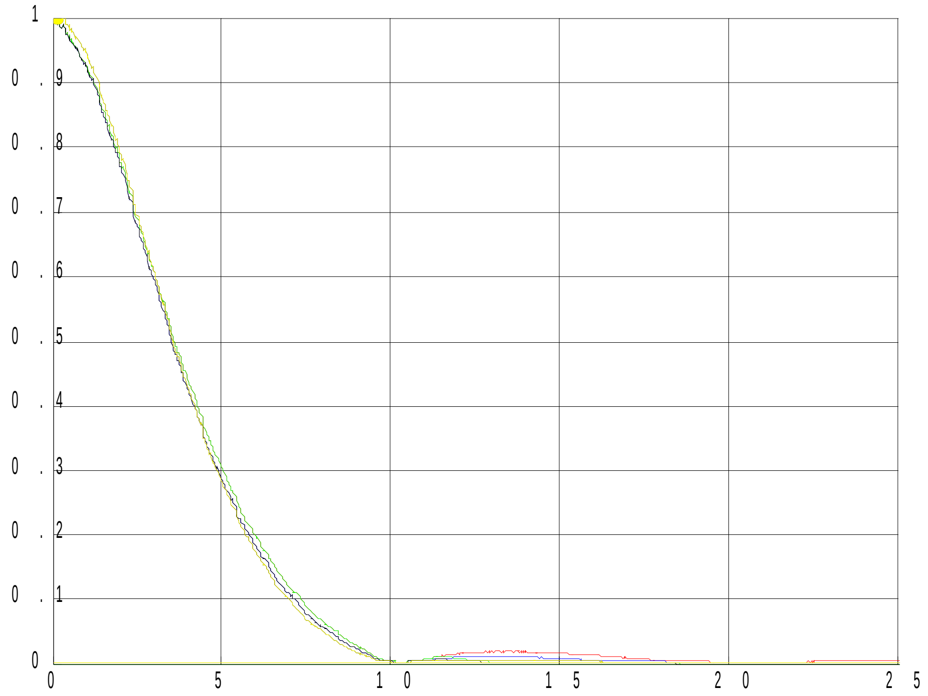


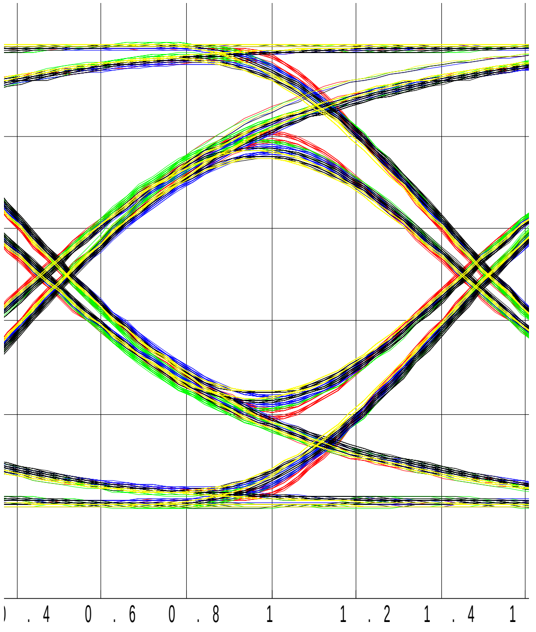
MCB to... 11.1 GHz 10 GHz

Red: ideal MCB, no filter
Blue: ideal MCB, 12 GHz BT4
Green: truncated MCB, no filter (solid: from 11.1, dashed: from 10 GHz)
Black: truncated MCB, 12 GHz BT4 (solid: from 11.1, dashed: from 10)
Yellow/black: no MCB, 7.5 GHz BT4 (target)

- Blue and black are much more alike than red and green
- Without scope filter, poor risetime reproducibility for fast edges

Check: slow eyes





- As expected, scope filter and compliance board have little effect with slow eyes
  - Except for crosstalk: out-of-band crosstalk should be excluded

Discussion: Part 1

- Scope bandwidth affects eye shape more than it affects jitter
- Uncontrolled aspects of compliance boards are significant with high bandwidth scope, for fastest edges
- Product receiver bandwidth is lower than any of the scope bandwidths
- Requiring a scope bandwidth much more than compliance board makes little sense
- Specifying observation bandwidth much more than product bandwidth gives misleading results
  - Over-estimates crosstalk (and reflection?) effects
  - Not reproducible – depends too much on compliance board
  - However, scope response also has tolerances
- For DDJ and DDPWS, scope bandwidth can be *reduced* after the event by post-processing in software
  - Improving accuracy, negligible cost in volume
- Post-processing to *increase* bandwidth magnifies any scope response errors
- Very difficult to post-process eyes taken with sampling scope

Either the compliance board *reference* loss should be specified up to 15 GHz, or a 12 GHz scope bandwidth should be specified, or both

Not proposing any change to compliance board actual specs, just the reference loss in equations 85-15 and 85-34, 83B-3, 83B-4, 86A-4 and 86A-5

Recommendations for Part 1

Not changing numbers or requiring different compliance boards or scopes

1. In equations 85-15 and 85-34, 83B-3, 83B-4, 86A-4 and 86A-5, change the upper frequency limit for the *reference* insertion loss from 10 or 11.1 GHz to 15 GHz
   - No change to compliance board and test fixture specifications
2. In 85.8.3.8 DDJ, change "the measurement bandwidth should be at least 20 GHz" to "the waveform is observed in a 12 GHz linear phase low pass filter response (such as a Bessel-Thomson response)"

(The next sentence is already "If the measurement bandwidth affects the result, it can be corrected for by post-processing.")

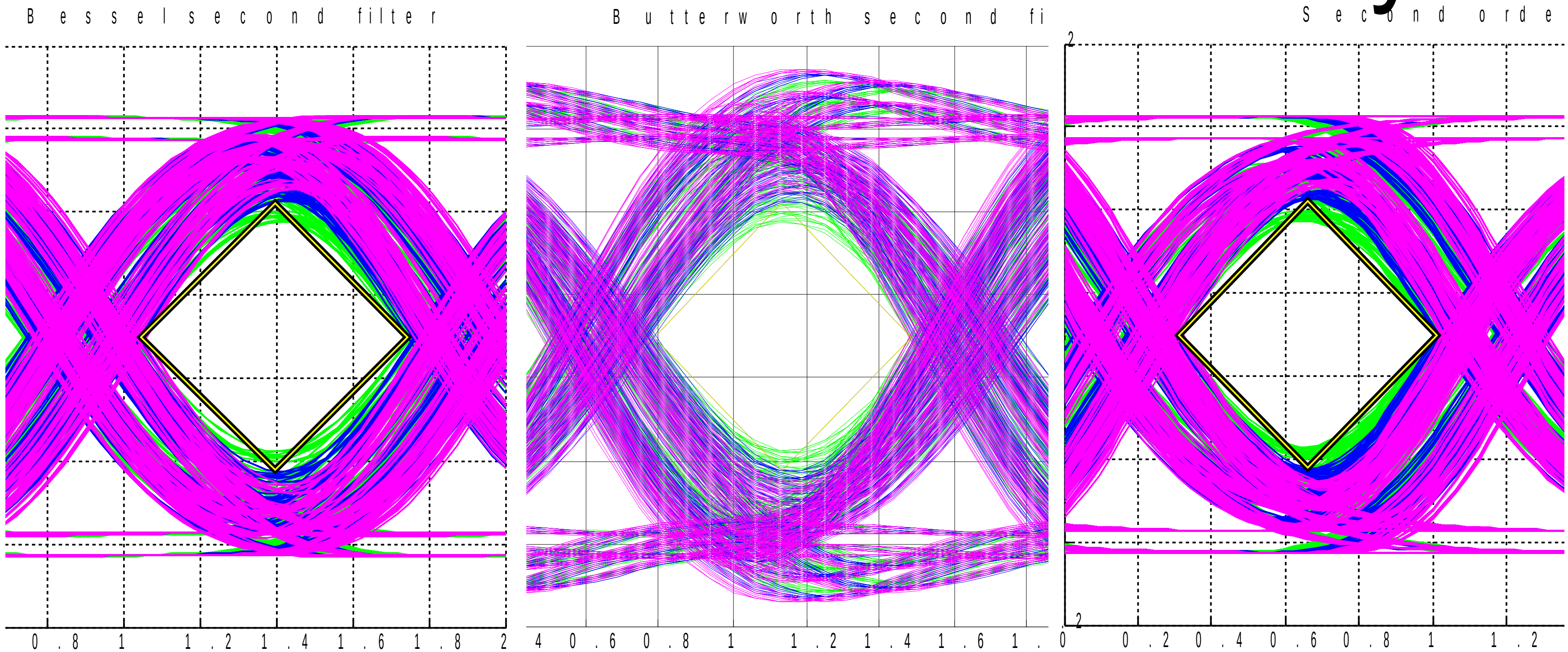
3. In 86A.5.3.3 Transition time, change "12 GHz low pass filter response" to "12 GHz linear phase low pass filter response (such as a Bessel-Thomson response)"
4. In 86A.5.3.4 DDPWS, change "measurement bandwidth is 12 GHz" to "measurement bandwidth is 12 GHz with linear phase (such as a Bessel-Thomson response)"
5. In 86A.5.3.6 Eye mask, change "bandwidth of 12 GHz." to "bandwidth of 12 GHz with linear phase (such as a Bessel-Thomson response)."

- This is not a test equipment standard and this does not bind test equipment manufacturers
- For transition time, DDJ and DDPWS, a higher bandwidth scope can be used and the waveform post-processed in software. This improves accuracy

Part 2: optical stressed eye

- Following new Clause 87 recipe
  - Fixed 0.05 UI SJ
  - BT4 filter, SI and limiter to create DDJ including DDPWS
  - Limiter
  - Second low-pass filter (2 types) and SI
  - Observe with 7.5 GHz BT4 representing scope
  - And observe with 6 GHz BT4 representing slow product receiver
  - Record pulse width shrinkage (PWS) in 7.5 GHz
  - Observe ISI at 0.1 UI offset (twice 0.05 in 52.9.10.4) in 7.5 GHz
  - Observe ISI vs. bandwidth

Three Clause 87 stressed eyes



- 1st SI = 0
- 2nd SI as much as allowed
- Green 9, blue 7.5, magenta 6 GHz BT4 observation filter
- Bessel with 7.5 GHz BT4 observation filter: PWS=0.24 UI
- Butterworth with 7.5 GHz BT4 observation filter: PWS=0.22 UI, wider eye
- 2nd order with 7.5 GHz BT4 observation filter: PWS=0.24 UI

Observations

- Filter profile for *these* filters has a mild effect on eye shape and symmetry
  - Will affect receivers with imperfect but acceptable decision point setting
  - Should not leave filter response wide open.
  - Could specify BT4 as usual, or at least "linear phase (such as a Bessel-Thomson response)"
- Pulse width shrinkage is much more than "at least 0.05 UI" given in 87.8.11.2
  - Text should be changed to closer represent SRS testers