Signaling Method Performance Results

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Presentation Flow

- Assumptions
- Algorithm approach
- Eye maps
- Conclusions

Purpose

- Find Equalization For Duobinary and CENRZ For 24 Representative IEEE Channels
- Generate Eye Diagrams
  - Measure Vertical and Horizontal Eye Opening
  - Set Limits and Determine Which Channels Served by Each Method
- Show perspectives on the relative performance of signaling methods
- Determine Which Signaling Method Covers Larger Number of Channels

Included in Model

- Channel
  - 0.4 pf added at each port (package), not IEEE model
  - 7.5 GHz single pole (Tx shaping)
- Equalization
  - 3-tap FFE least squares fit
  - Up to 5-tap DFE
- Crosstalk
  - NEXT – assumed worse case than FEXT
  - 2 Aggressors, randomly phased
    - Choose Worst (Highest SDD21 Magnitude) for Molex, Intel
    - Match Case by Case For Tyco Channels
- Clock Recovery

Included in Model

- Wideband Noise
  - Added at Receiver
  - Value = 1.46 mV RMS (per IEEE)
- Quantization
  - FFE
    - Duobinary Uses 8 Levels, Range Based on All Channels
    - NRZ Uses 8 Levels, Range Based on All Channels
    - Range for Duobinary is different from range for NRZ
  - DFE
    - 16 Levels Based on Post-Cursor Range For Current Channel
- Jitter
  - DJ of 0.4 UI-pp Added (intent was to compensate for inability to sim RJ)
  - Phase Modulation at 1.1 GHz

Limitations

- Only 1000 Bits
  - RJ not included
  - Worst case events may not appear
    - Wideband noise
    - Crosstalk
- Iterative Adjustment of FFE and Sample Point Would make results more optimistic & typical in actual implementation
- Quantization effects may be larger in actual implementation
- **Belief:**
  - **We feel this evaluation is realistic, balanced and valuable, when viewed in total, given the limitations, assumptions and impairments.**

Math Progression

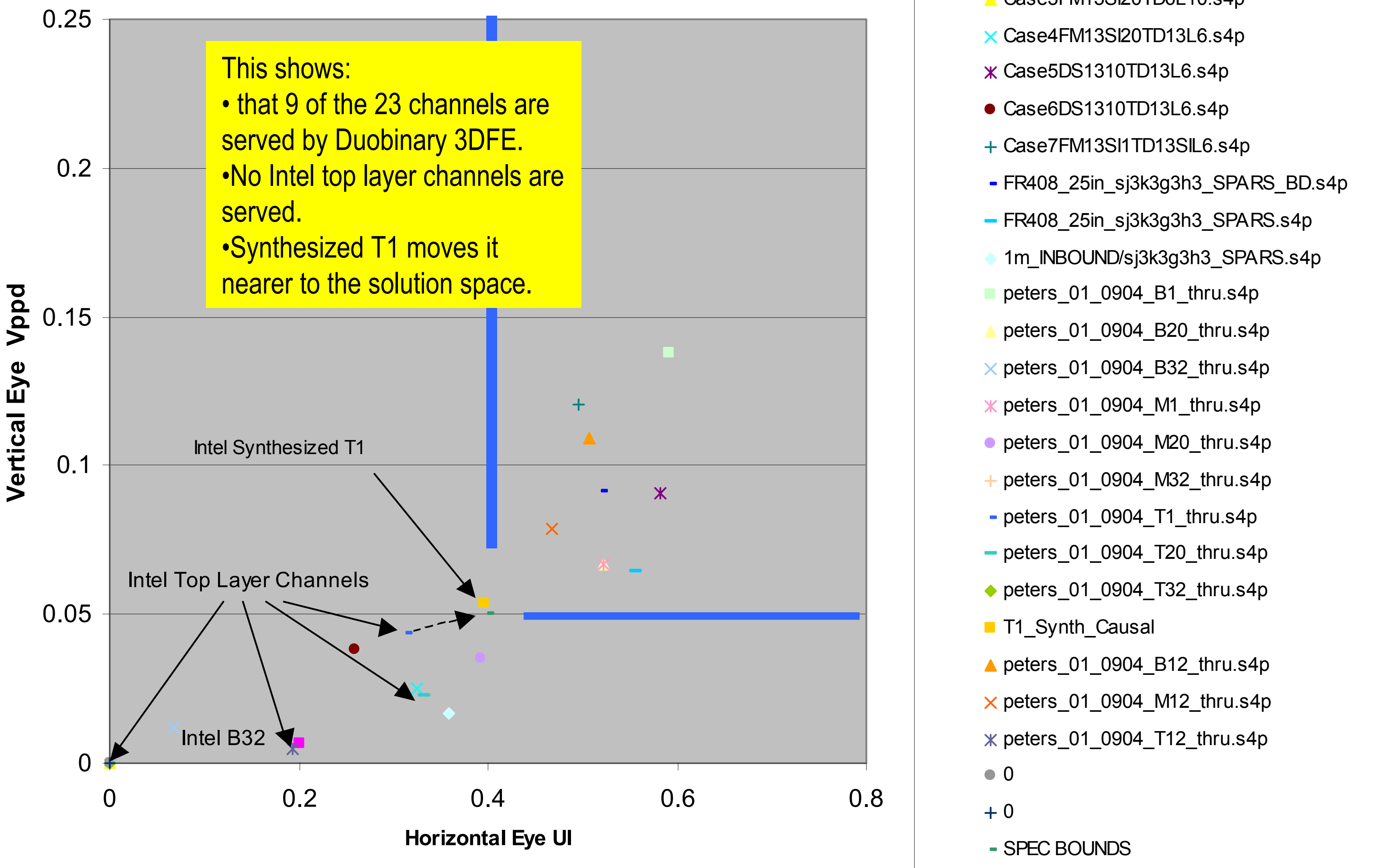
- Chapter 1 -- Determine Impulse Response of Through Channel.
- Chapter 2 -- Read in Bit Stream, Do Clock Recovery
- Chapter 3 -- Find FFE.
- Chapter 4 -- Find Tx Signal and FFE DC Gain.
- Chapter 5 -- Show FFE-Equalized Bit Streams, Eyes, by Assembling Equalized Impulses.
- Chapter 6 -- Find Quantized Tx FFE Tap Values.
- Chapter 7 -- Repeat (Chap 5) For Comparison.
- Chapter 8 -- Calculate DFE Taps.
- Chapter 9 -- Add DFE to Result of Chap 7, No Jitter.
- Chapter 10 -- Add DFE to Result of Chap 7, With Jitter.
- Chapter 11 -- Generate the Crosstalk.
- Chapter 12 -- Add Wideband Noise.
- Chapter 13 -- Generate the DFE Quantization.
- Chapter 14 -- Repeat Chap 7 With Xtalk, DFE Quantization, Jitter, and Noise.

NOTE: This is not a StatEye simulator

Comparison Approach

- Receiver performance is viewed from a *similar complexity* basis…assuming:
  - 5-tap NRZ DFE is a reasonable complexity bound
  - 3-tap DB DFE and 5-tap NRZ DFE are reasonably similar in complexity

Duobinary 3FFE / 3DFE



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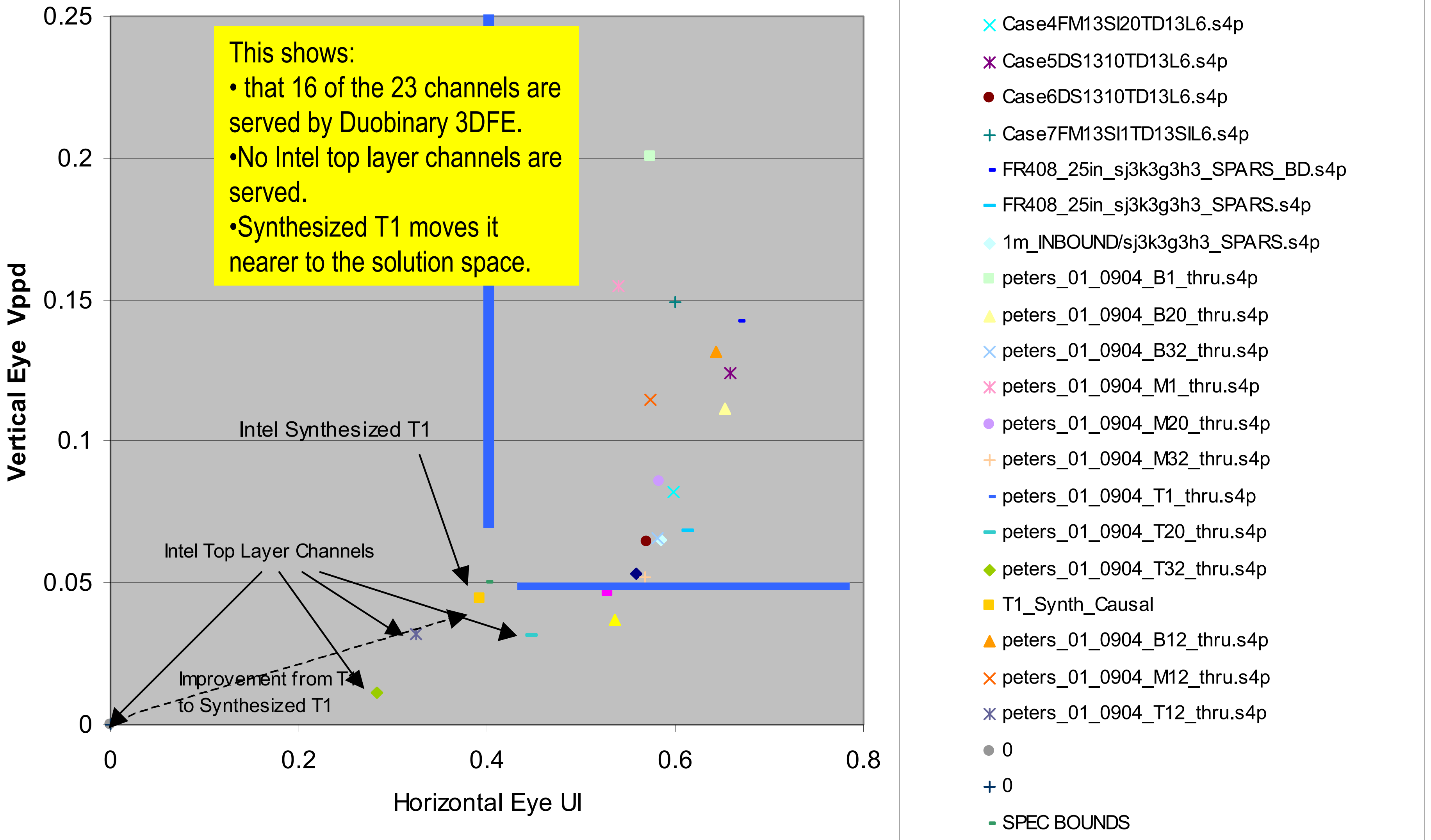
NRZ 3FFE / 5DFE



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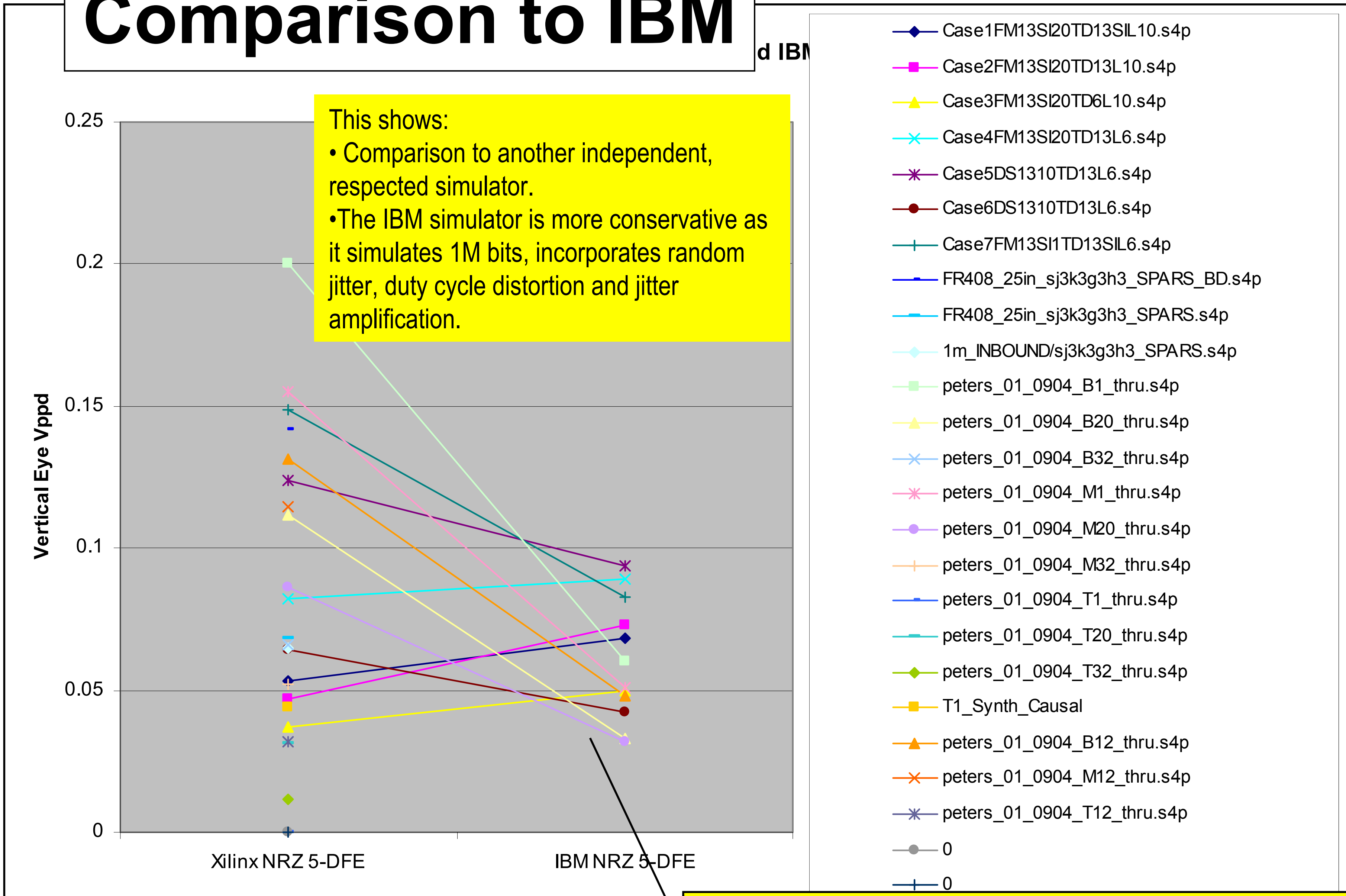
Comparison to IBM



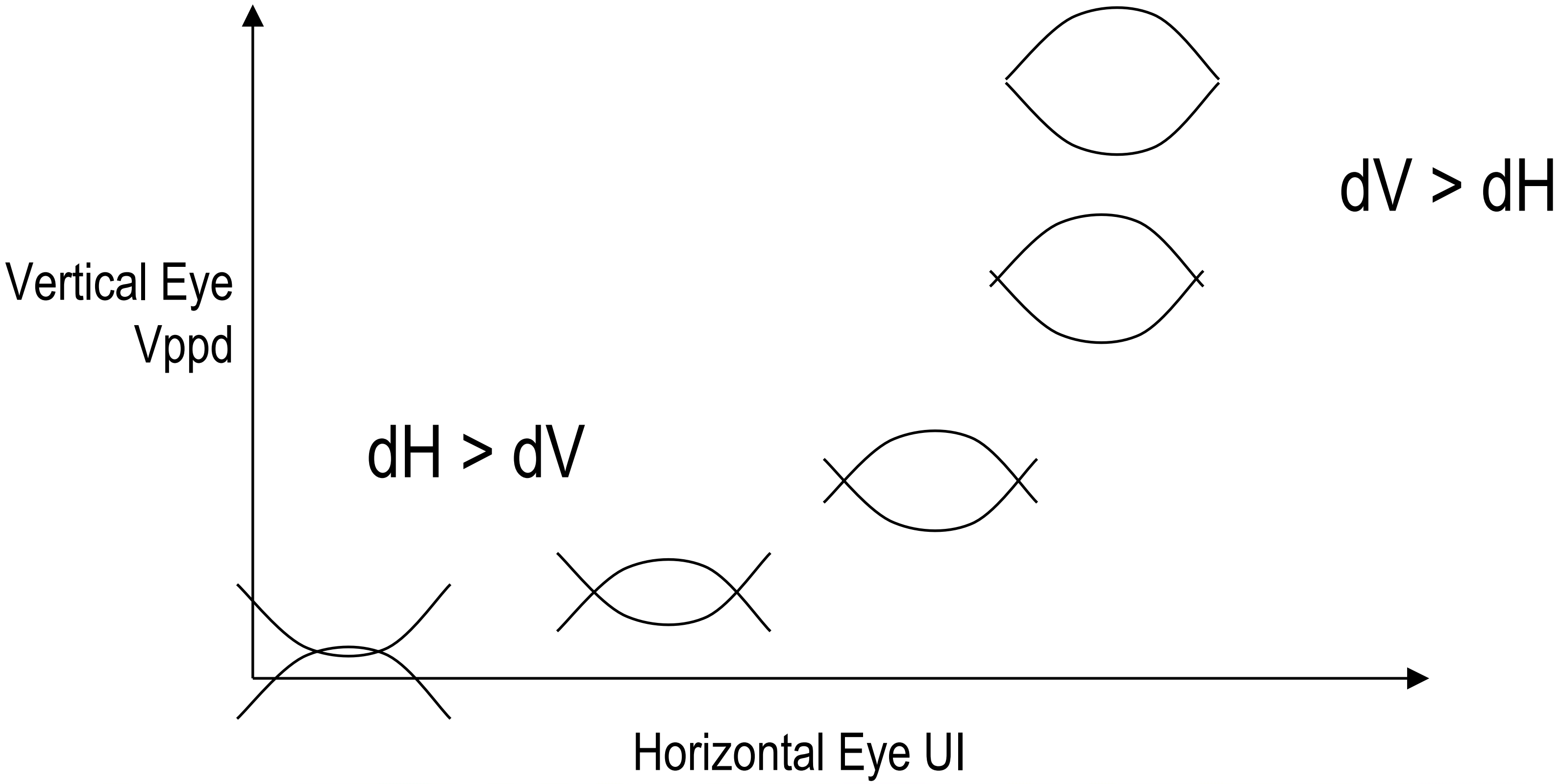
This shows:

- Comparison to another independent, respected simulator.
- The IBM simulator is more conservative as it simulates 1M bits, incorporates random jitter, duty cycle distortion and jitter amplification.

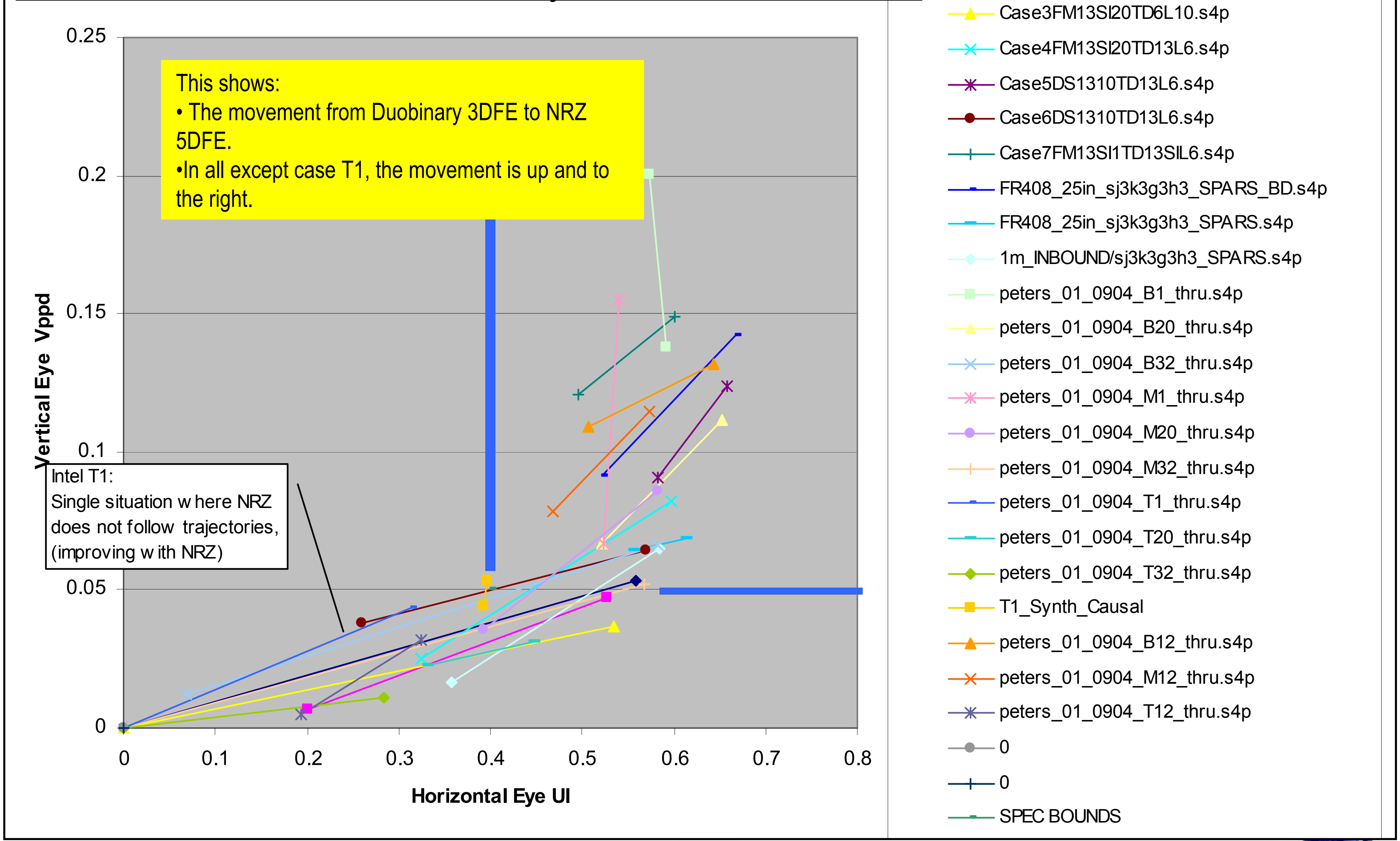
Data from IEEE Coding Table v4-3_abler_mar05
Assumes Abler data is x% margin beyond 30mVppd

General Eye Shapes vs. Trajectory

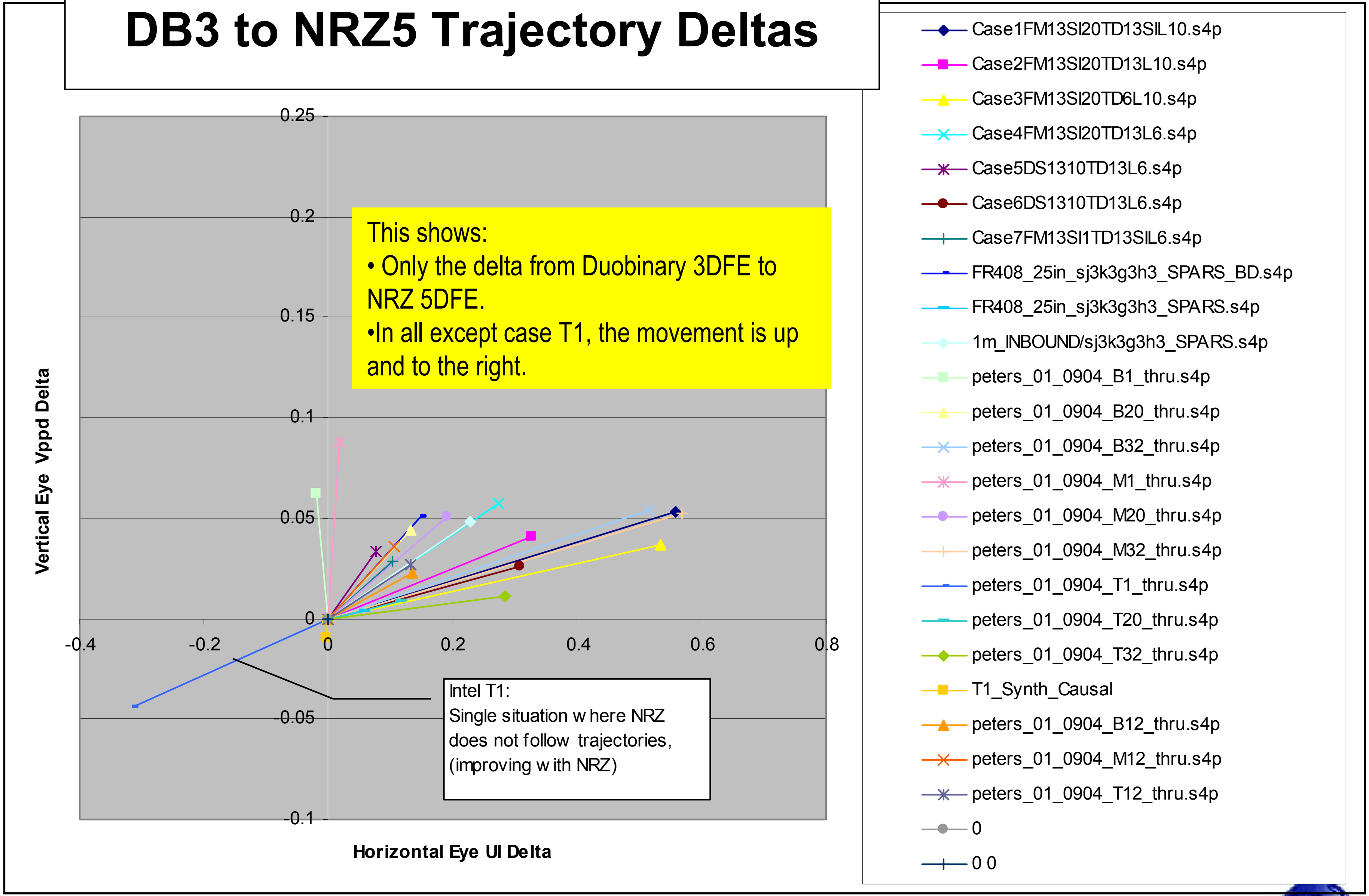
- Diagram of d-horiz / d-vert for an eye



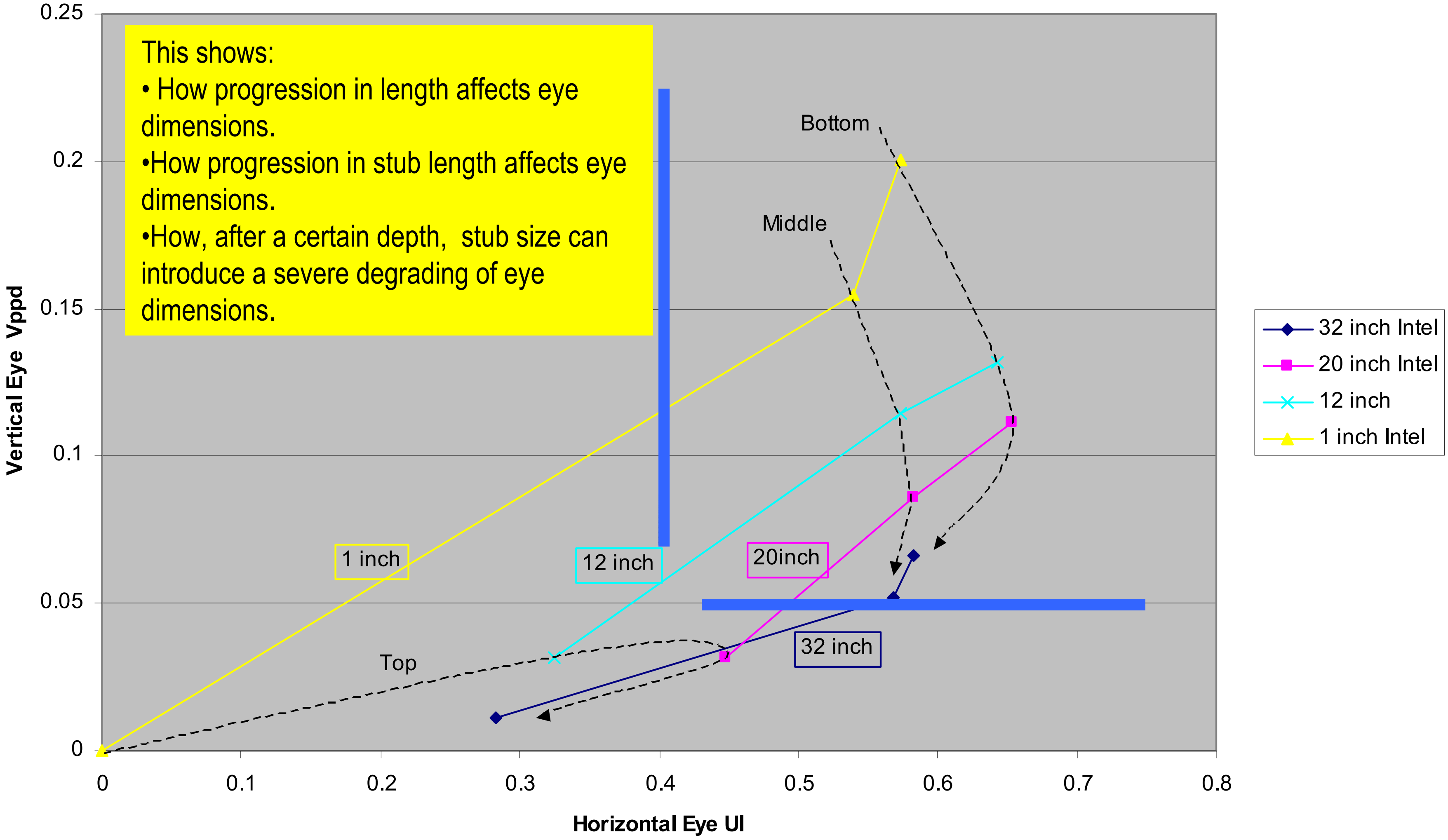
DB3 to NRZ5 Trajectories



DB3 to NRZ5 Trajectory Deltas

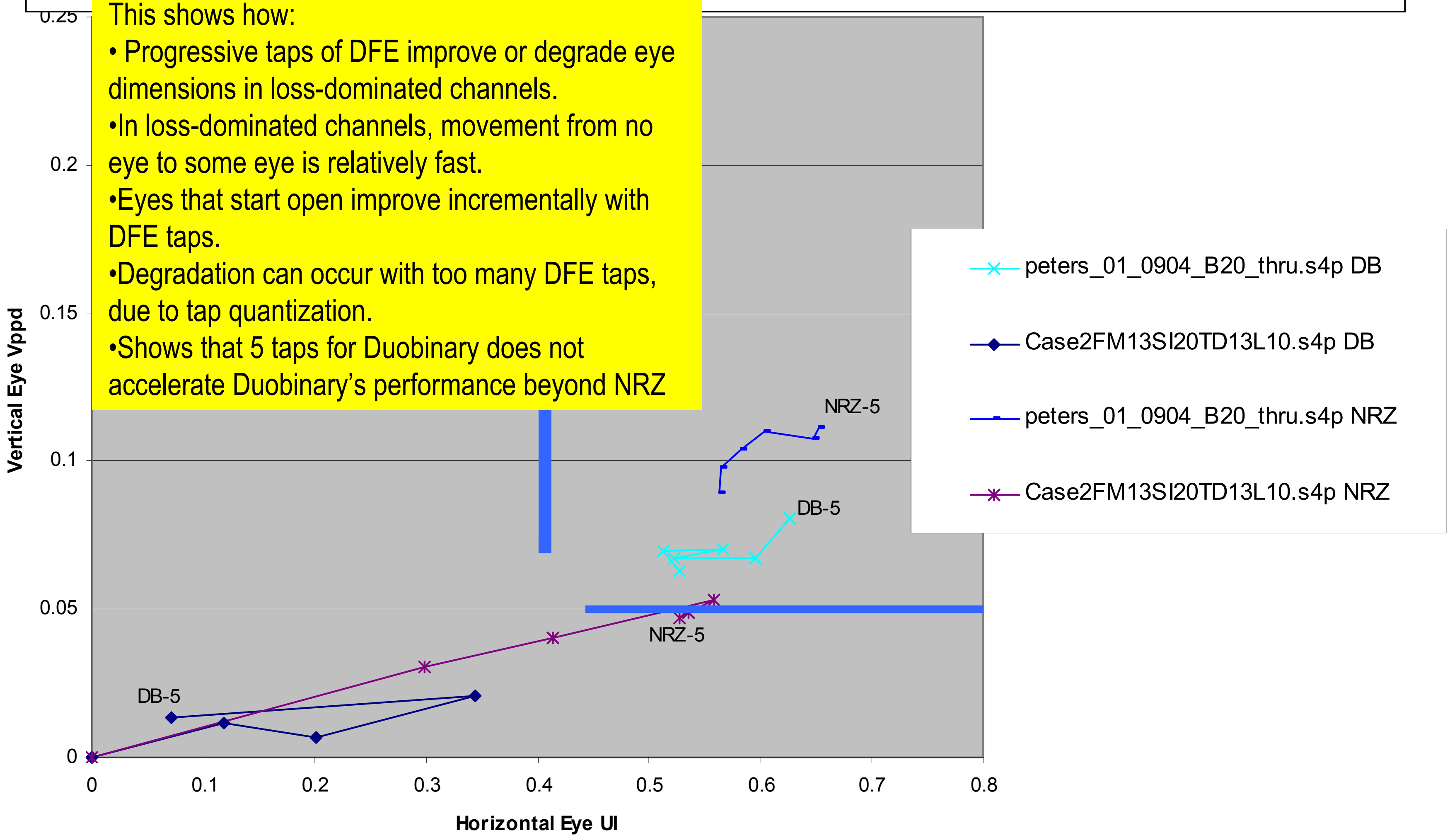


Trajectories vs. Stub vs. Length



Trajectories vs. #-taps
Long Channels

This shows how:
- Progressive taps of DFE improve or degrade eye dimensions in loss-dominated channels.
- In loss-dominated channels, movement from no eye to some eye is relatively fast.
- Eyes that start open improve incrementally with DFE taps.
- Degradation can occur with too many DFE taps, due to tap quantization.
- Shows that 5 taps for Duobinary does not accelerate Duobinary's performance beyond NRZ



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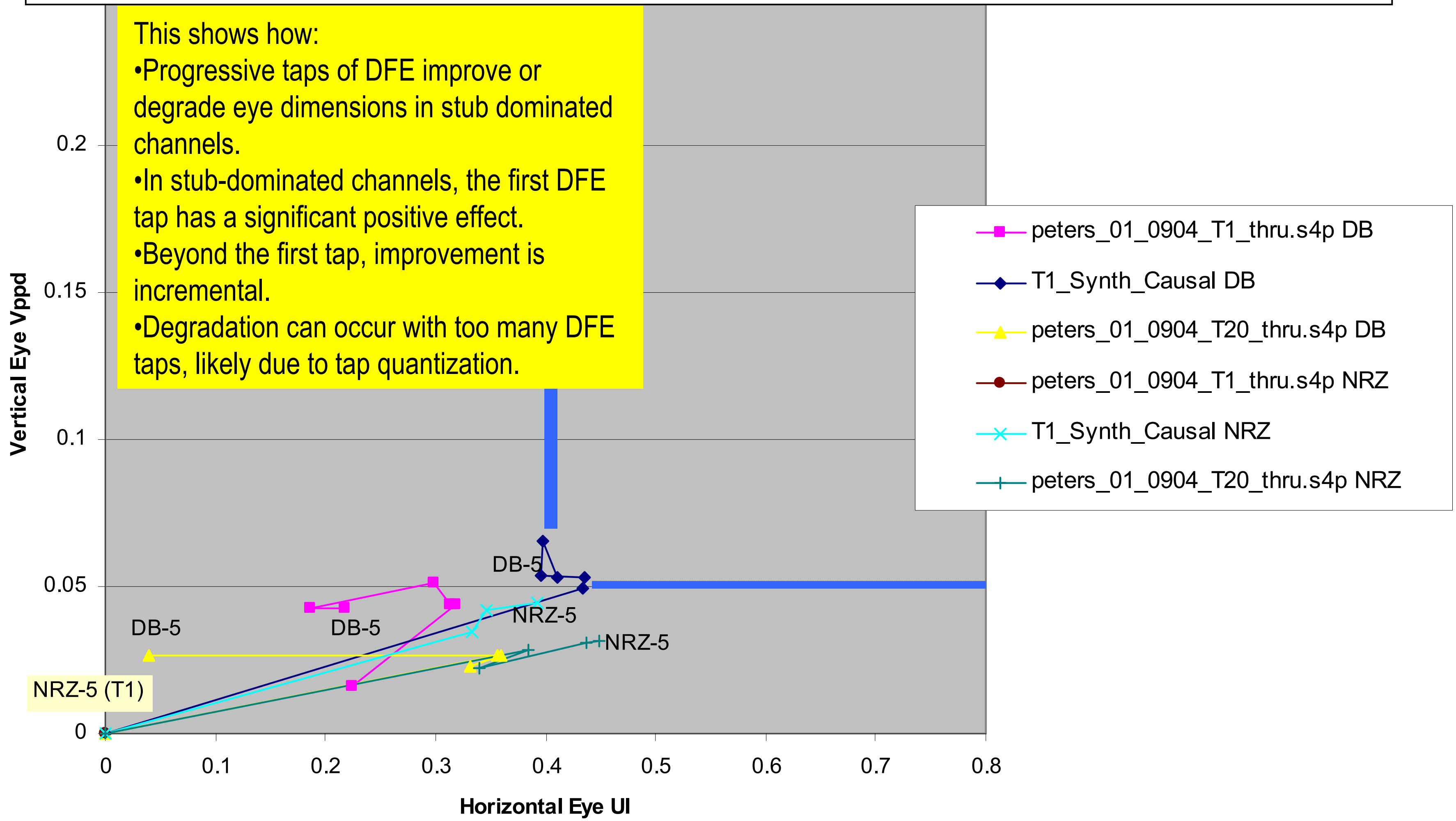
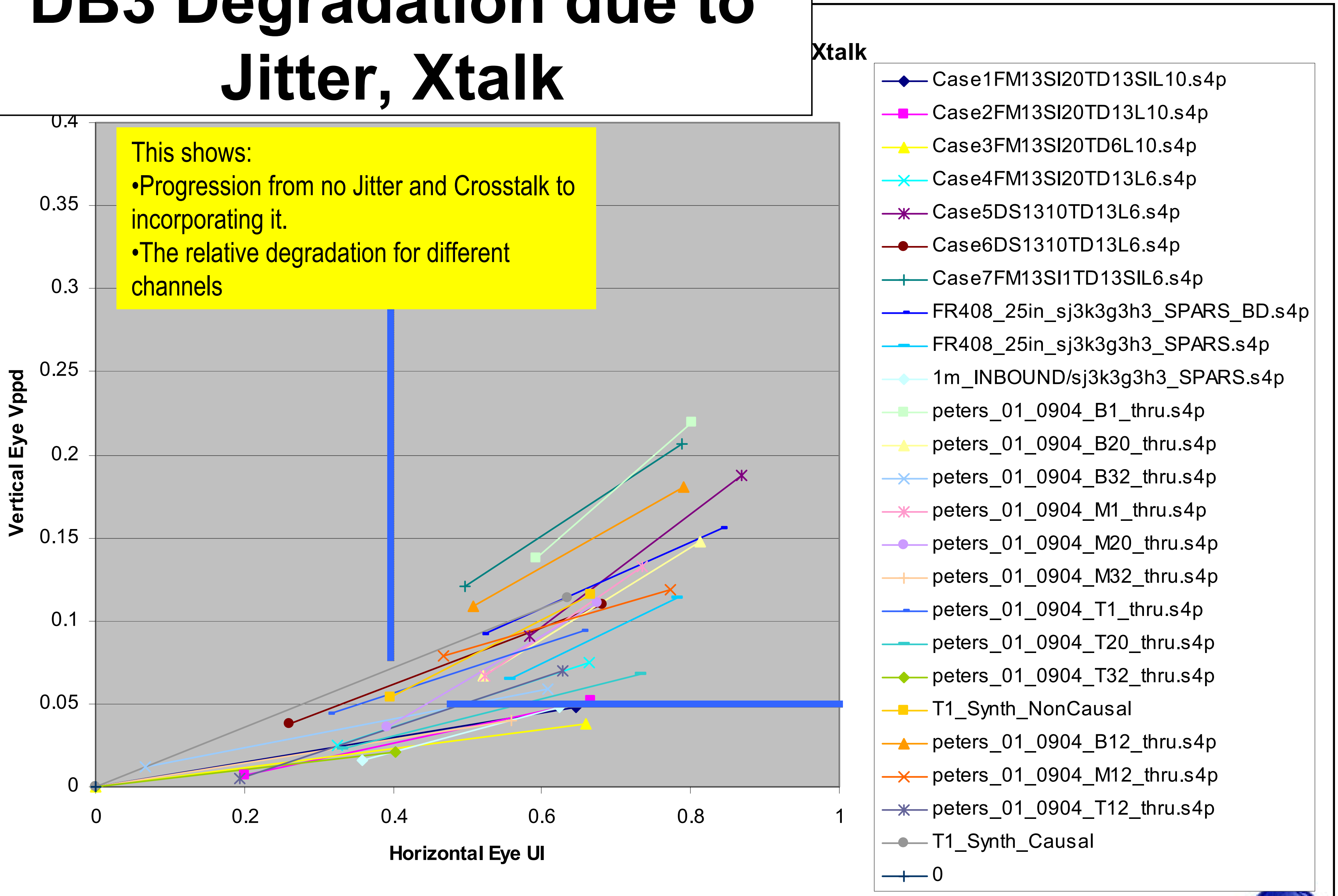
Trajectories vs. #-taps
Stub Channels

This shows how:

- Progressive taps of DFE improve or degrade eye dimensions in stub dominated channels.
- In stub-dominated channels, the first DFE tap has a significant positive effect.
- Beyond the first tap, improvement is incremental.
- Degradation can occur with too many DFE taps, likely due to tap quantization.



DB3 Degradation due to Jitter, Xtalk



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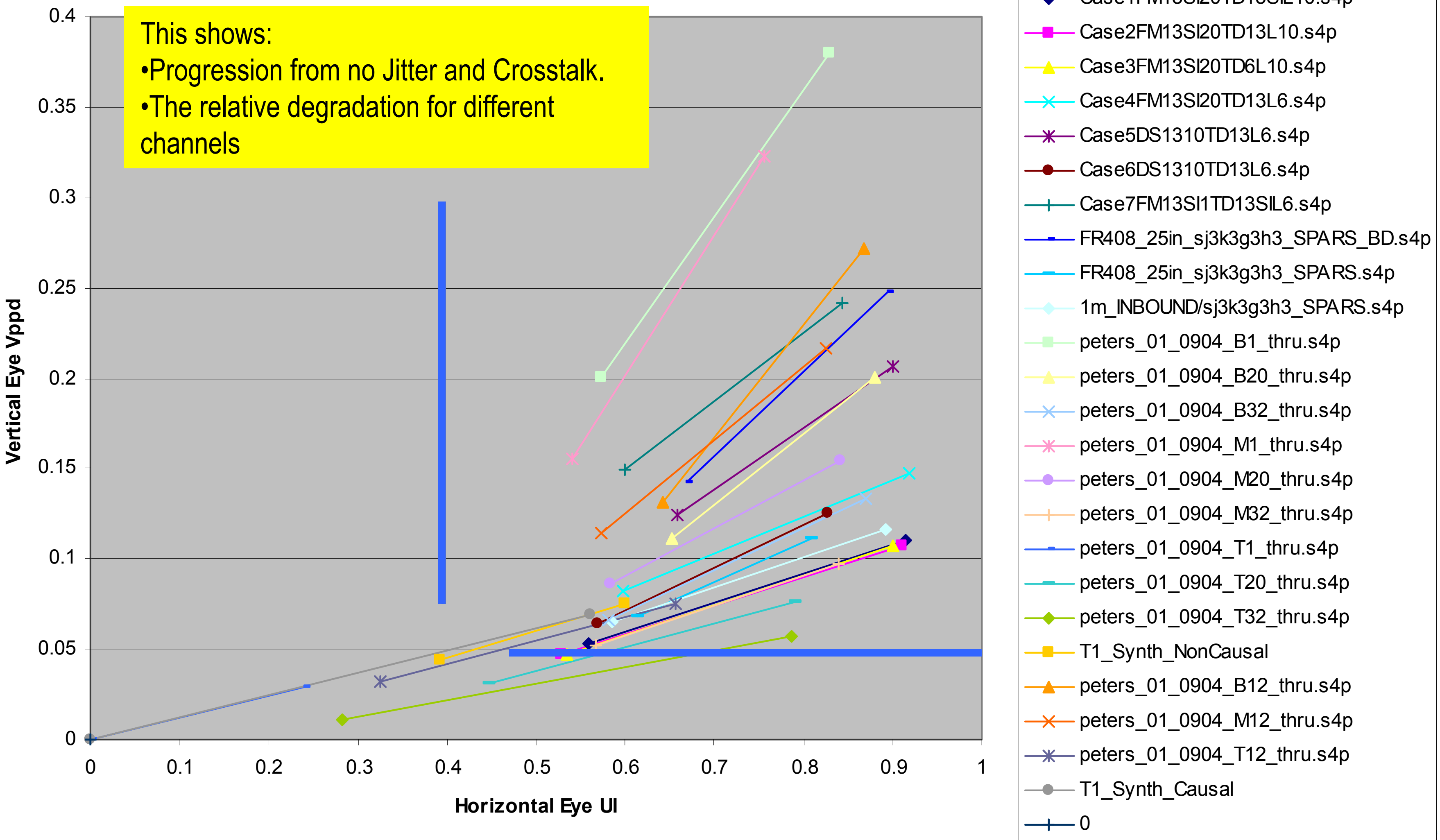
NRZ5 Degradation due to Jitter, Xtalk

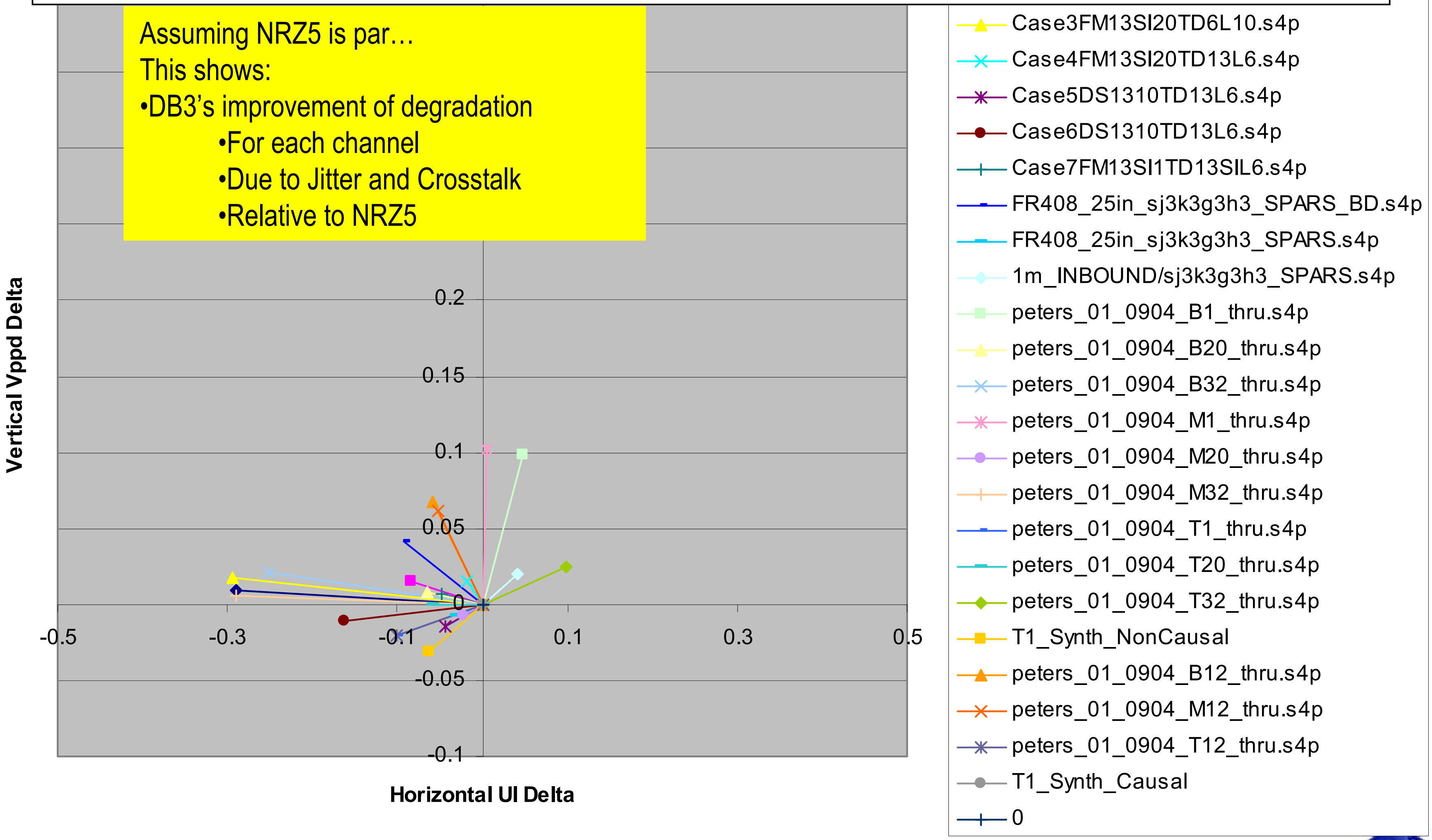
This shows:

- •Progression from no Jitter and Crosstalk.
- •The relative degradation for different channels

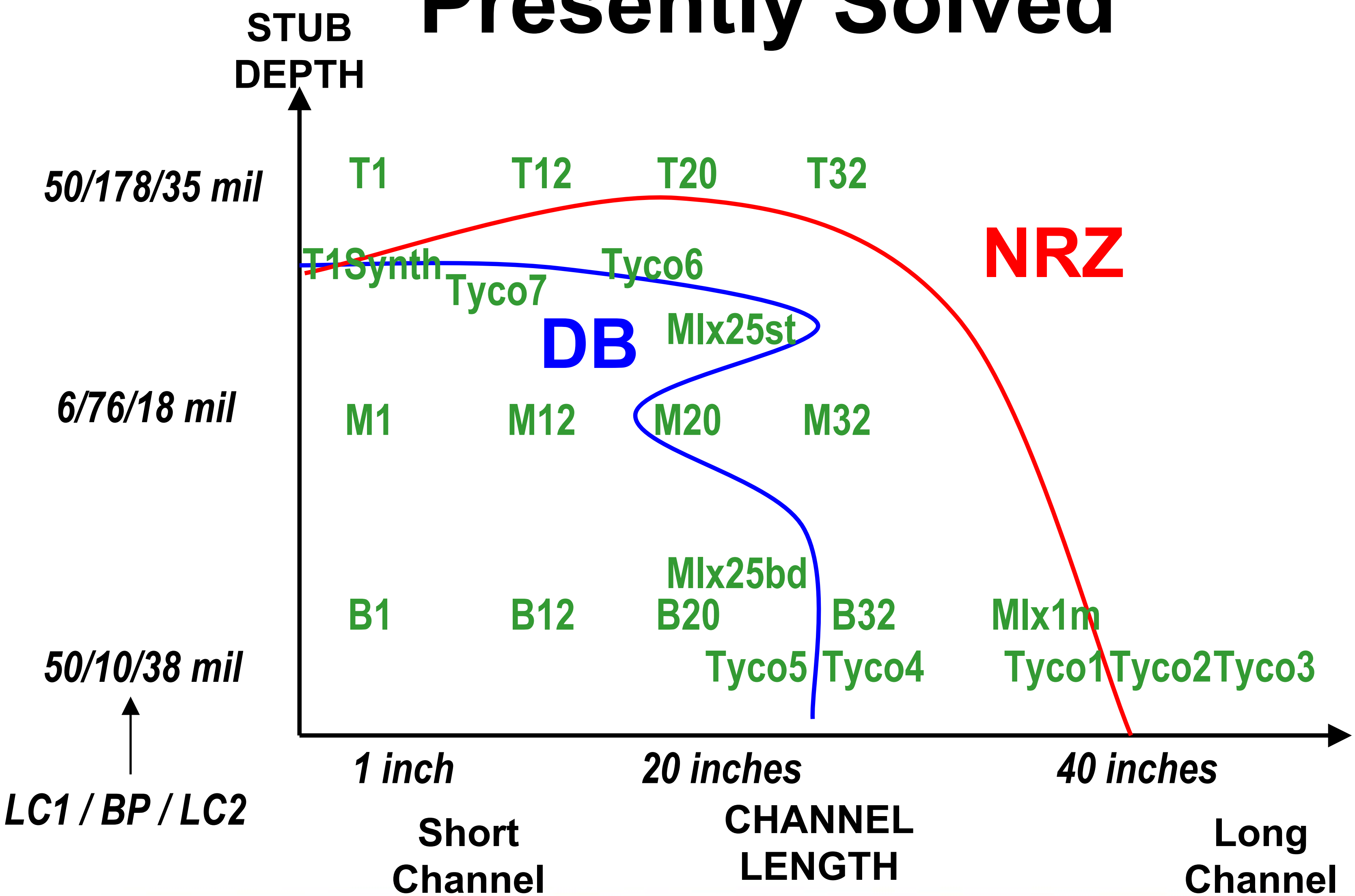


Relative Delta due to Jitter, Xtalk

Assuming NRZ5 is par…
This shows:
- DB3's improvement of degradation
  - For each channel
  - Due to Jitter and Crosstalk
  - Relative to NRZ5



Graphical View of Channels Presently Solved



Conclusions

- Long stubs are an obstacle
- NRZ serves more channels than Duobinary
  - The unsolved channels are important market applications
  - Some channel improvements are possible that are compatible with High Volume Manufacturing techniques
  - Further improvements should be considered for both signaling and channel in order to solve these important channels
- IEEE 802.3ap should be moved forward based on this and other data

Appendix Slides

Channel List

Case1FM13SI20TD13SIL10.s4p
Case2FM13SI20TD13L10.s4p
Case3FM13SI20TD6L10.s4p
Case4FM13SI20TD13L6.s4p
Case5DS1310TD13L6.s4p
Case6DS1310TD13L6.s4p
Case7FM13SI1TD13SIL6.s4p
FR408_25in_sj3k3g3h3_SPARS_BD.s4p
FR408_25in_sj3k3g3h3_SPARS.s4p
1m_INBOUND/sj3k3g3h3_SPARS.s4p
peters_01_0904_B1_thru.s4p
peters_01_0904_B20_thru.s4p
peters_01_0904_B32_thru.s4p
peters_01_0904_M1_thru.s4p
peters_01_0904_M20_thru.s4p
peters_01_0904_M32_thru.s4p
peters_01_0904_T1_thru.s4p
peters_01_0904_T20_thru.s4p
peters_01_0904_T32_thru.s4p
T1_Synth_Causal
peters_01_0904_B12_thru.s4p
peters_01_0904_M12_thru.s4p
peters_01_0904_T12_thru.s4p