Transmit linearity measurement method proposal

In support of Comment #145

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Motivation to change R_{LM} definition

- Current specification
  - Based on the min. eye opening between the 4 PAM levels measured using a custom pattern
  - It allows large deviations from ideal levels
    - Up to 20% in asymmetric case
    - Up to 10% on the positive side of ES1 and ES2
- COM models the eye-opening reduction but assumes perfect ISI cancellation by the DFE
  - Not practical for a DFE to achieve this when TX levels are distorted
  - RX compression further aggravates this issue
  - Impact on margin is proportional to the max error on ES1 and ES2 and DFE tap weights
  - Need tighter constraint on ES1 and ES2
- Proposed method
  - Use PRBS13Q for level measurement
  - Constrain the levels enough to mitigate the impact on the RX
  - But allow a reasonable margin for TX designers

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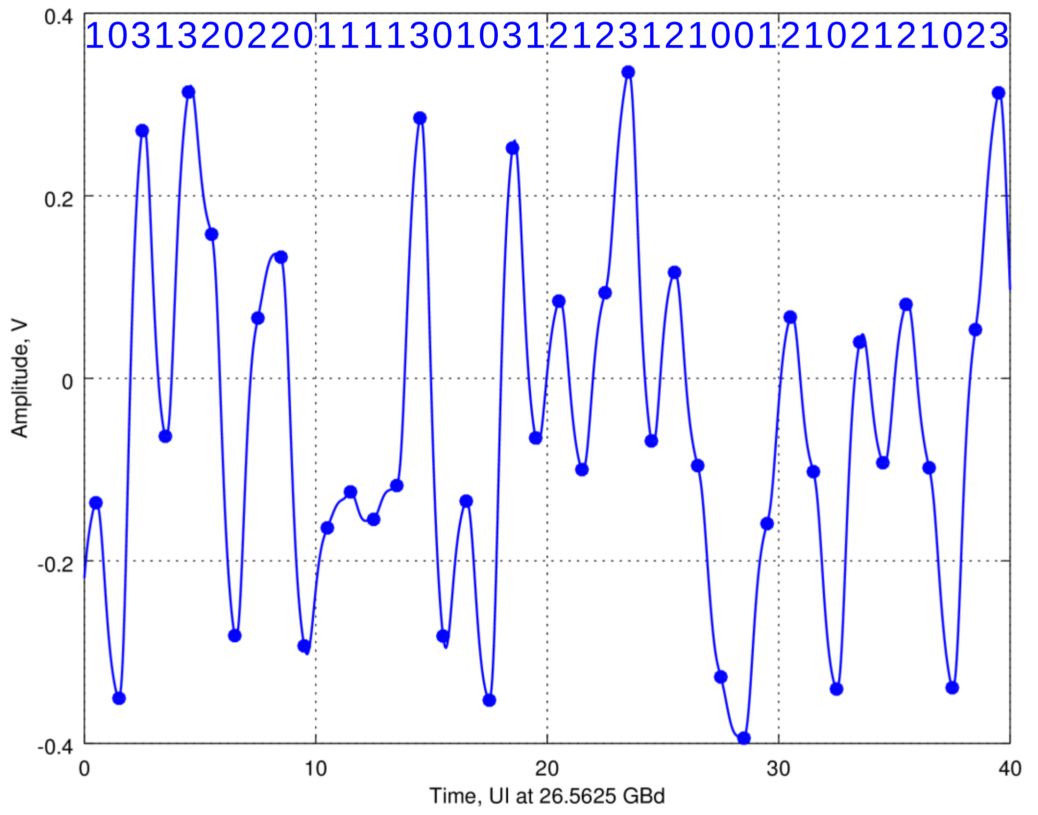
Proposed method – Level measurement

PAM4 signal level measurement

- Transmit the PRBS13Q test pattern
- Acquire the transmitted waveform using the procedure described in 85.8.3.3.4
  - Waveform must be aligned to the test pattern
  - E.g., the first M samples correspond to the first bit of the test pattern, the last M samples correspond to the last bit of the test pattern
- Sample the waveform once per unit interval
- Compute the PAM4 signal levels
  - V_A is the mean value of the 0 samples
  - V_B is the mean value of the 1 samples
  - V_C is the mean value of the 2 samples
  - V_D is the mean value of the 3 samples



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Significance of the result

- For a linear system, it is proportional to the amplitude of the pulse response cursor
- It agrees with convention for eye amplitude "AVxxx" measurement in Annex 120E

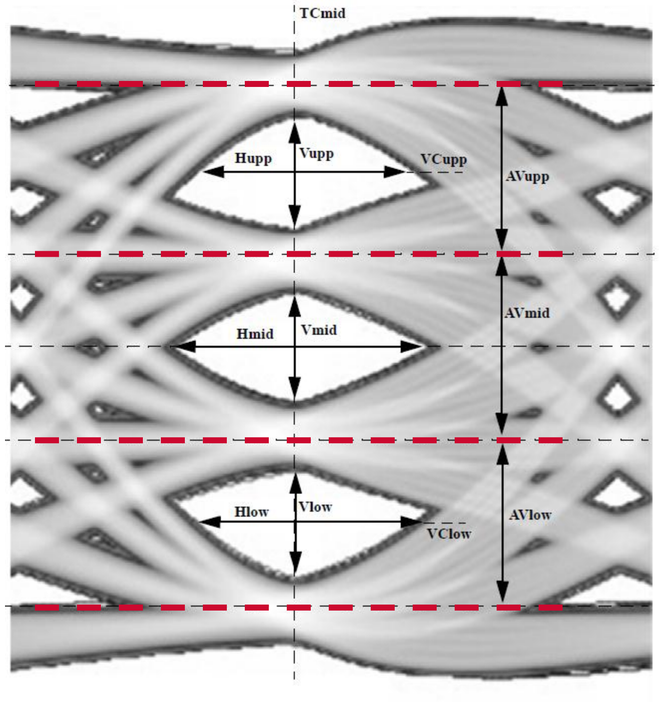
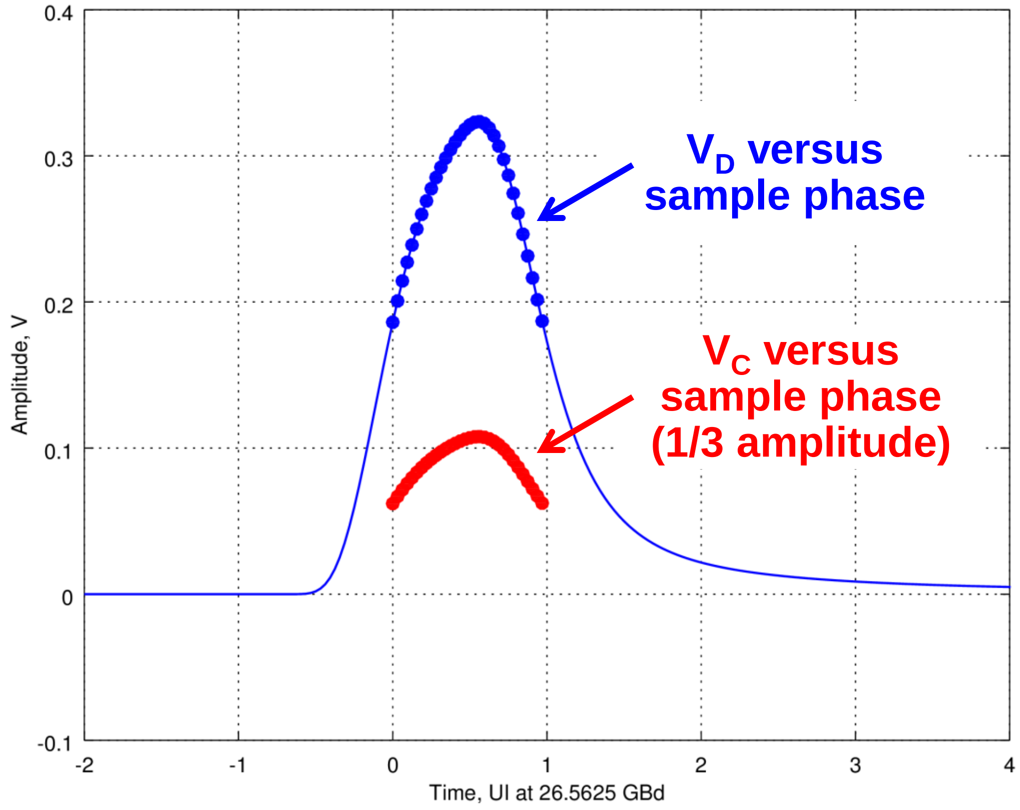


Figure 120E–12—PAM4 eye measurements



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Sensitivity to sampling phase

- The measured signal levels are sensitive to sampling phase
- However, ratios of signal levels are specified and not the signal levels themselves
  - E.g., ES1, ES2, R_{LM}
- The ratios are considerably less sensitive to sampling phase
- Option #1: Specify that a sampling phase close the middle of unit interval be used
- Option #2: Average over all sampling phases

Proposed method – R_{LM} computation

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R_{LM} and SNDR

- Using the measured signal levels, compute:
  - $L_{mid} = (L_D + L_A)/2$, $ES1 = (L_B - L_{mid})/(L_A - L_{mid})$, and $ES2 = (L_C - L_{mid})/(L_D - L_{mid})$
- Define R_{LM} to capture max. deviation from ideal
  - **R_{LM} = min(3*ES1, 3*ES2, 2 − 3*ES1, 2 − 3*ES2)**
  - Keep the limit same as before at 0.95
  - This allows ES1 and ES2 to assume values of +/− 5% around ideal
- Define ES = (ES1 + ES2)/2
- Compute the linear fit pulse and SNDR using levels [−1, −ES, +ES, +1]

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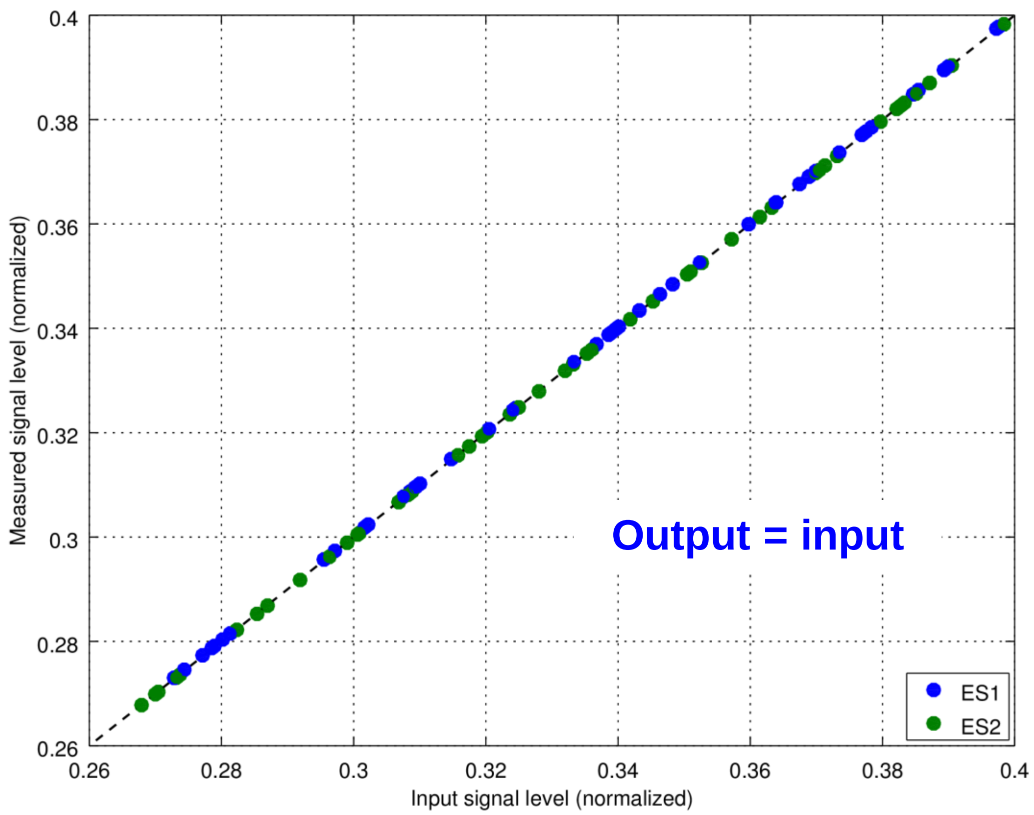
Verification of the method

- Test 50 random pairs of offsets E_B and E_C spanning +/−20%
  - {−1, −(1+E_B)/3, (1+E_C)/3, 1} are the normalized signal levels
- Synthesize transmitted waveform with the offset signal levels
  - COM-based model
  - Table 120D–7 parameter values, z_p = 30 mm
  - TP0-TP0a model is 38 mm of host PCB trace
- Measure V_A to V_D using proposed method
  - Averaged over all sampling phases
- Calculate ES1 and ES2 per this proposal
- Compare to the input signal levels



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