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Precise time. Synchronized.

Testing Hybrid Clocks
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Outline of Presentation

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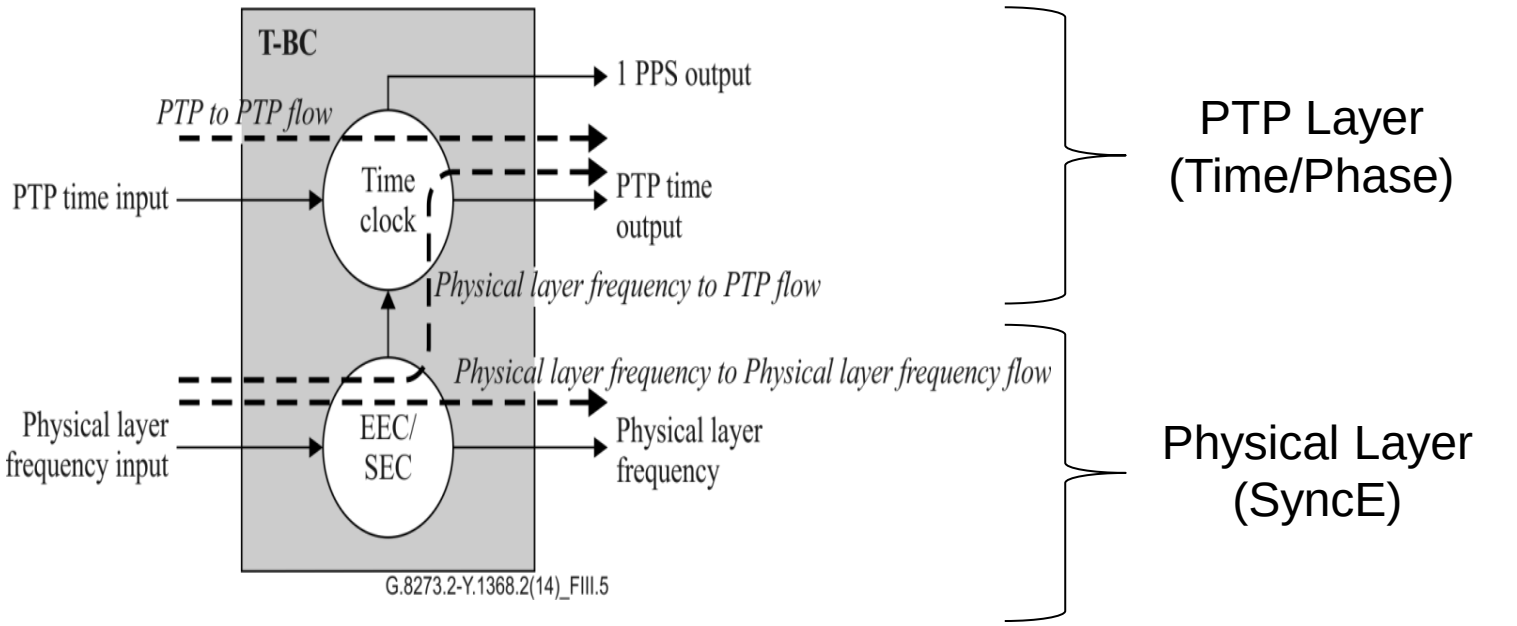
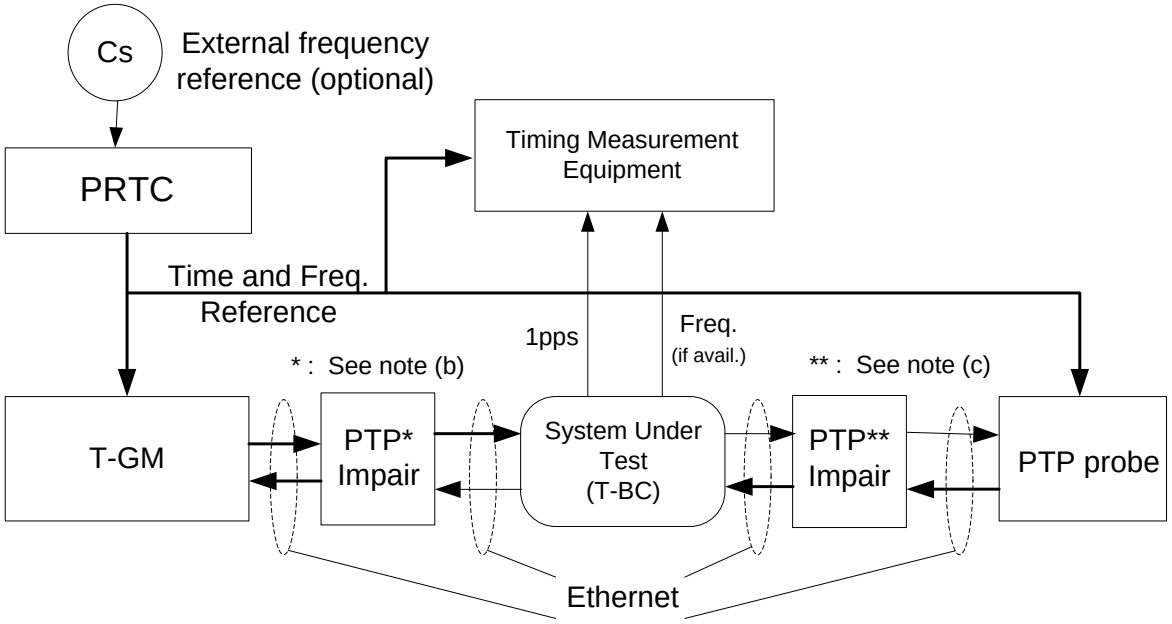
- Hybrid Clocks (PTP plus SyncE)
- Testing Methodology (ITU-T Rec. G.8273)
- Desired Behavior
- Impact of nonlinear elements and aliasing
- Measuring response at 1-PPS resulting from sinusoidal excitation in SyncE using frequency selective method
- Examples
- Concluding Remarks

Hybrid Clock (PTP plus SyncE)



- Model of Hybrid clock (G.8273.2) showing the physical layer (SyncE) feeding into the time layer (PTP)
- Testing of “hybrid” aspect includes measurement of response of time-clock output (PTP or 1 PPS) to an excitation in the physical layer reference input (SyncE)

Testing Methodology (G.8273)



- General Testing includes measurement of generated noise, noise tolerance, and noise transfer
- Hybrid clock testing adds the need to measure the transfer from physical layer input to time output

Desired Behavior (G.8273.2)

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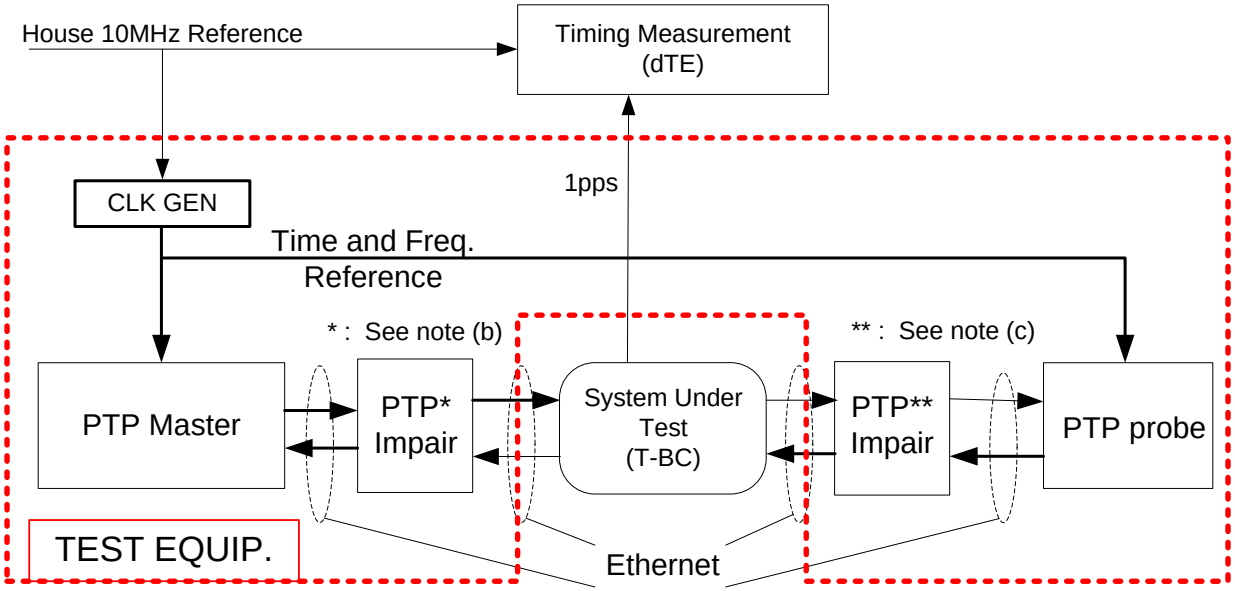
Table III.1 – Transfer functions applicable to a T-BC

Input/output on the T-BC	Transfer function
PTP input to PTP output PTP input to 1 PPS output	0.05-0.1 Hz low-pass filter
Physical layer frequency input to physical layer frequency output	1-10 Hz low-pass filter
Physical layer frequency input to PTP output Physical layer frequency input to 1 PPS output	[0.05-0.1; 1-10] Hz band-pass filter

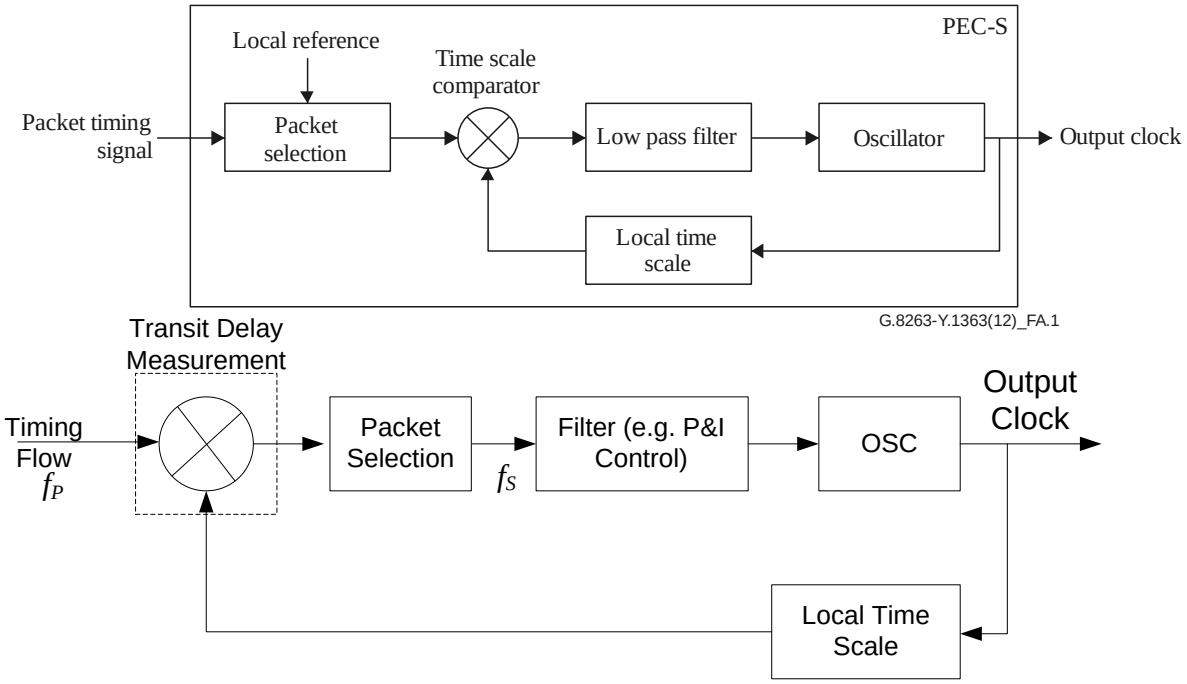
- "Hybrid" aspect: band-pass filter behavior from physical layer (SyncE) input to time output (PTP or 1-PPS)
- Issue #1:
  - Highest wander frequency (theoretically) in 1-PPS output is 0.5Hz
  - Highest wander frequency (theoretically) in PTP output is $0.5 \cdot f_P$ Hz
- Issue #2: Non-linear elements and (permitted) noise generation impact measurement – G.8273.2 alerts user that response curves are not "flat"

Testing Methodology (G.8273)



- Introduce sinusoidal wander of amplitude 125ns (250ns peak-to-peak) and desired frequency in SyncE going to UUT
- Measure response at time output (1-PPS and PTP)
- Compute transfer characteristic (at that frequency)
- Repeat with additional choices of test (wander) frequency

Presence of non-linear elements

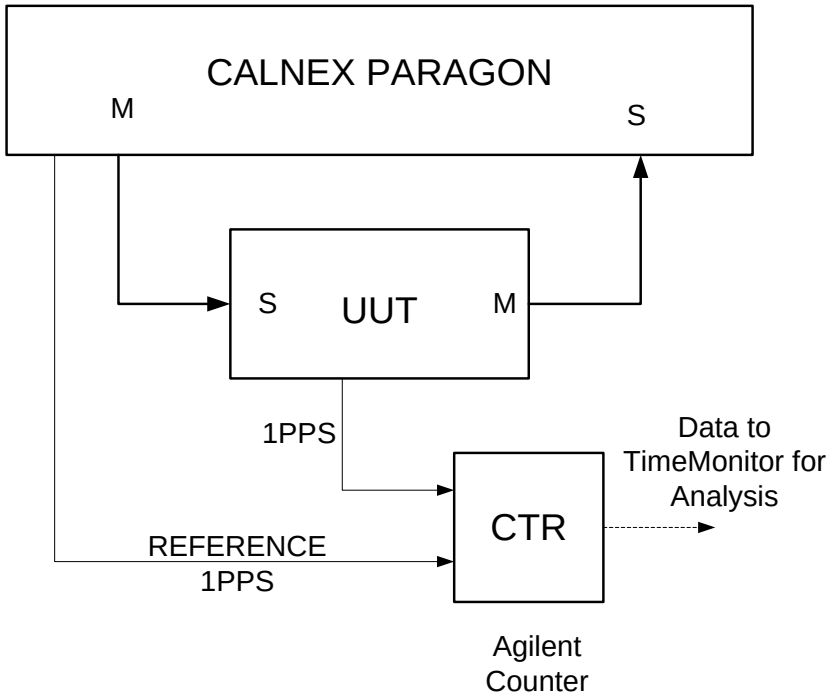


Packet Clock model in G.8263 (appears linear-time-invariant)

Packet Clock model indicating presence of non-linear element (more precise)

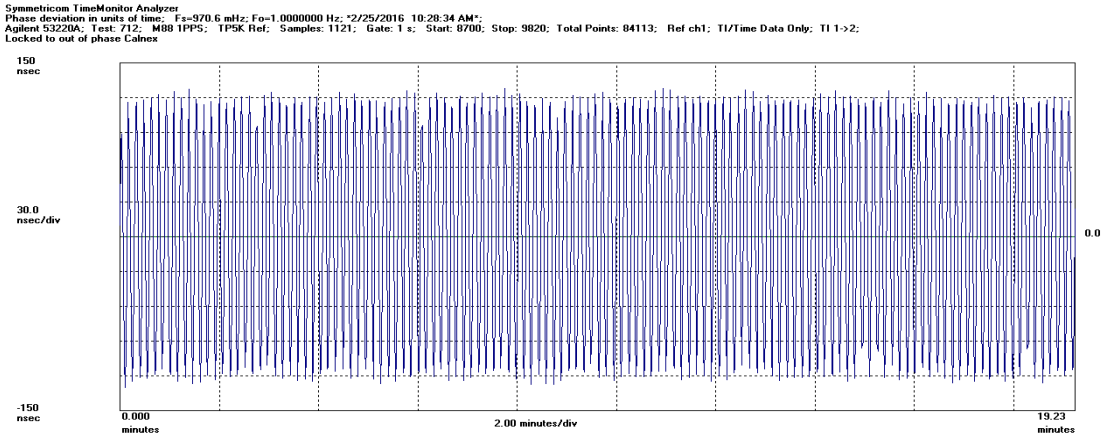
- Packet selection is not linear-time-invariant
- Presence of non-linear element means that the “frequency response” descriptor is approximate
- Nonlinearities can introduce inter-modulation products

Testing Methodology (G.8273)

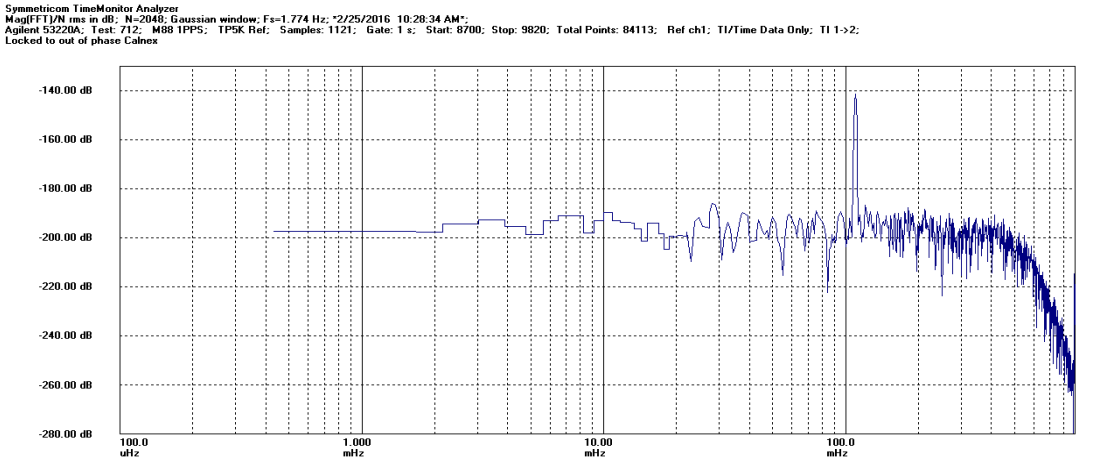


- Test Equipment (Paragon-X) clock used as “reference”
- Measurement of wander component in 1-PPS done by spectral analysis of measured time error
- Frequency of wander component in 1-PPS identified as the aliased component

SyncE-to-1-PPS test (0.11Hz)



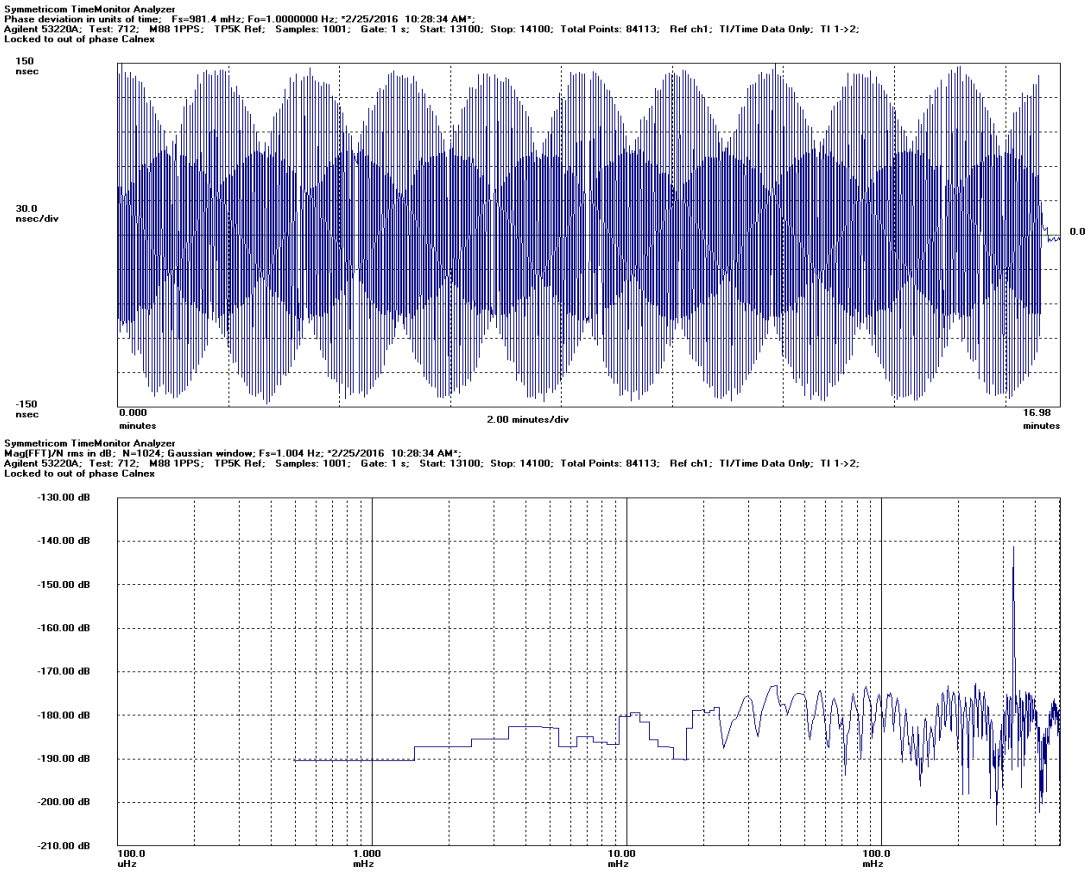
Measurement (1-PPS)
Peak-to-peak: 258ns



Spectral analysis
Amp. at 0.11Hz = 122ns

- Establishing amplitude as half of peak-to-peak is affected by noise generated

SyncE-to-1-PPS test (0.33Hz)

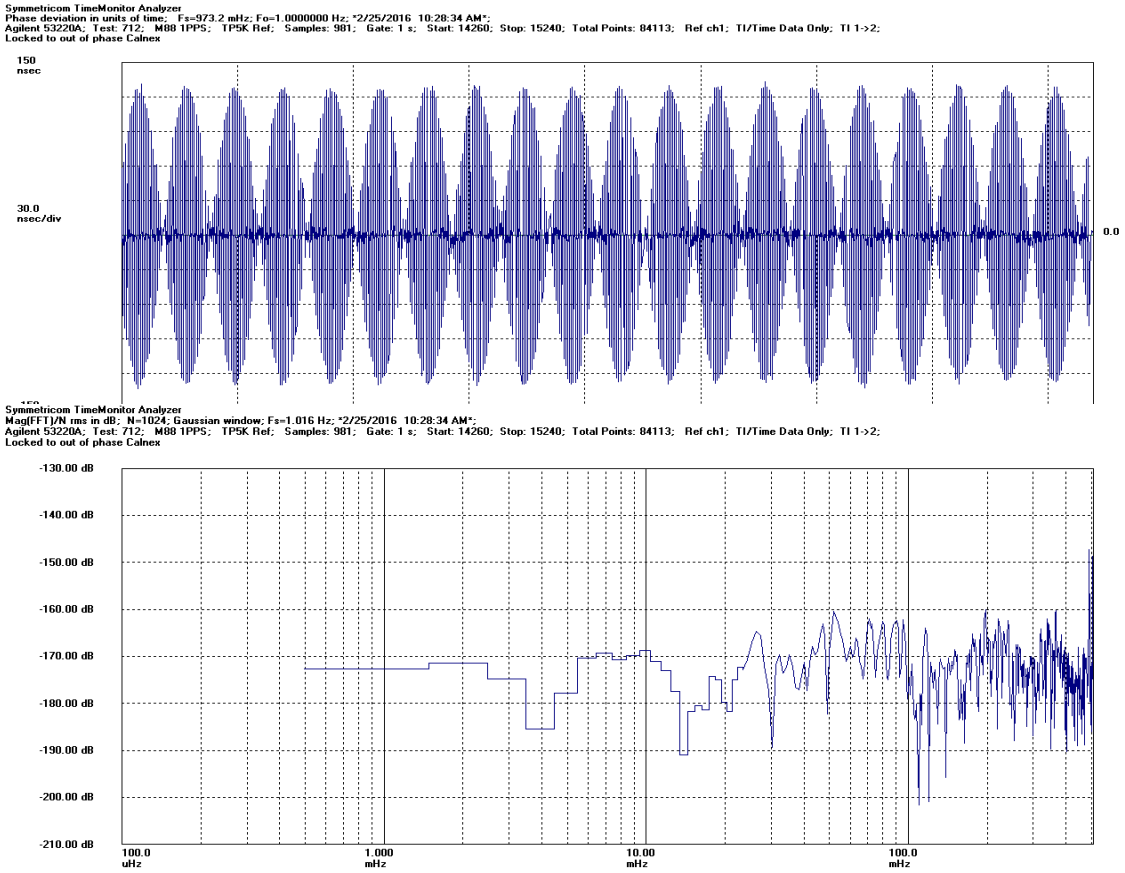


Measurement (1-PPS)
Peak-to-peak: 296ns

Spectral analysis
Amp. at 0.33Hz = 122ns

- Non-linear behavior, intermodulation, and aliasing quite striking

SyncE-to-1-PPS test (0.51Hz!)

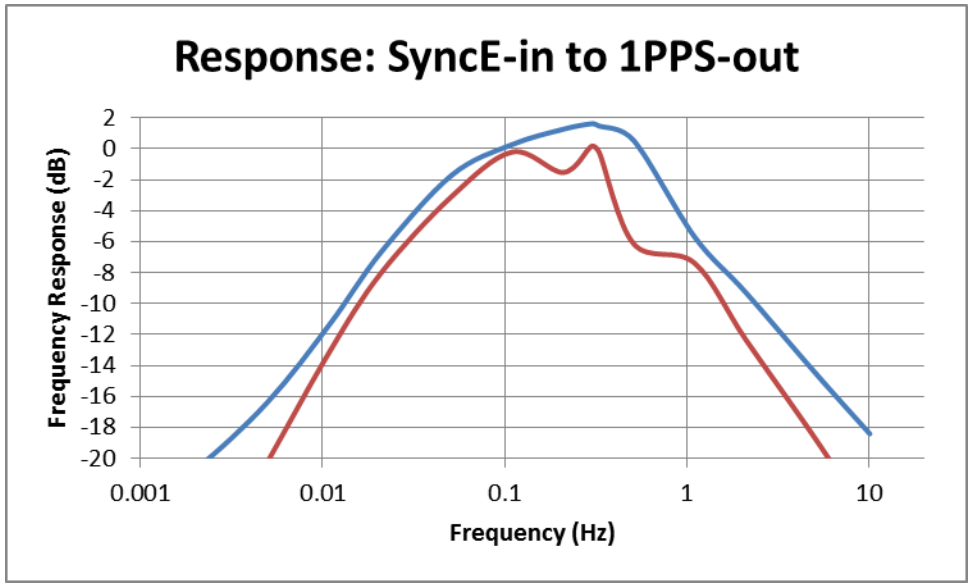


Measurement (1-PPS)
Peak-to-peak: 266ns

Spectral analysis
Amp. at 0.49Hz = 62ns

- Output amplitude established at 0.49Hz (aliased version of 0.51Hz)

Frequency Response (SyncE – PTP)



Blue: response measured in terms of peak-to-peak

Red: response measured using frequency-selective method

- Note that behavior is band-pass as expected (desired)
- Pass-band is “rounded” (as anticipated in G.8273.2)
- Frequency-selective measurement more precise and less affected by noise, intermodulation

Concluding Remarks

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- Testing hybrid clocks involves the additional step of verifying the transfer behavior from physical layer input to time output
- Packet-based clocks inherently have a non-linear aspect which renders common models such as “frequency response” approximations
- Measurement of response to a sinusoidal input requires a frequency-selective measurement method such as Discrete Fourier Transform (DFT) analysis

Questions?

Thank You

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