An Assessment of Real-Time Background Noise in 10GBASE-T Systems

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Real-Time/Time-Domain Noise Measurements Purpose & Goals

- Purpose – Characterize background noise in representative systems that are candidates for 40GBASE-T PHYs
  - Support the P802.3bq PHY Baseline Proposal ad hoc's request for "…measurement results of background noise in systems, including broadband, stationary, and nonstationary narrowband sources."
  - Why? System background noise power may be a significant factor in optimizing 40GBASE-T PHY designs

- Goals - This is a 2nd follow-on assessment intended to
  - Evaluate system background noise levels using time-domain measurement techniques
  - Provide better insight in to difference-mode noise properties

Methodology Overview

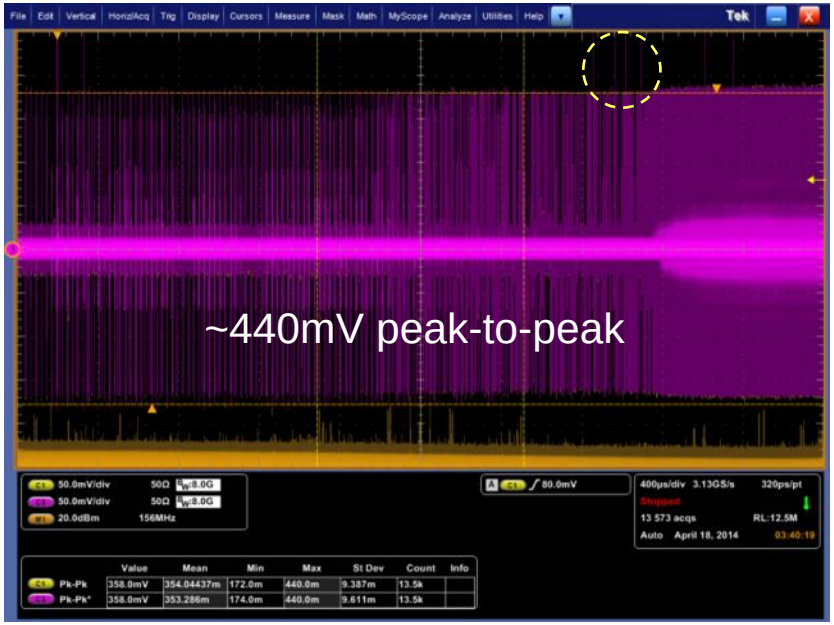
- Characterize system background noise as measured with a real-time oscilloscope
  - Measure system noise at PHY
    - PHY active but with all transmitters disabled
    - Probe as close as possible to PHY pins with DC blocks (SMA acquisitions) or differential probe
  - Capture (image only) long-term noise and any transients over several minutes to days using infinite persistence display mode
  - Calculate noise from FFT of time-domain acquisitions

2x SMA Probes

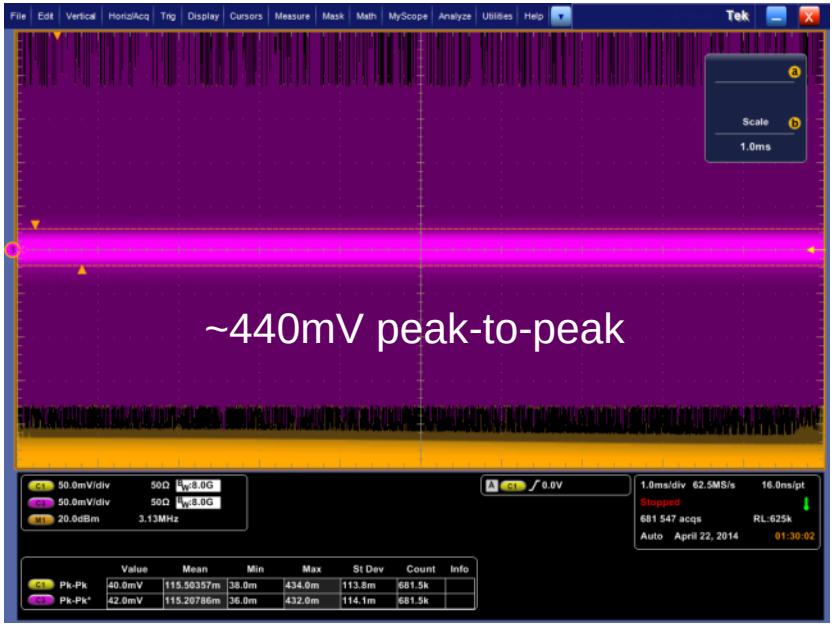
Differential Probe

Representative SMA Signal Acquisitions*

Short-term (~0.25h)



Long-term (~72h)



Short-term and long-term acquisitions are similar; long-term appears to be “more of the same”

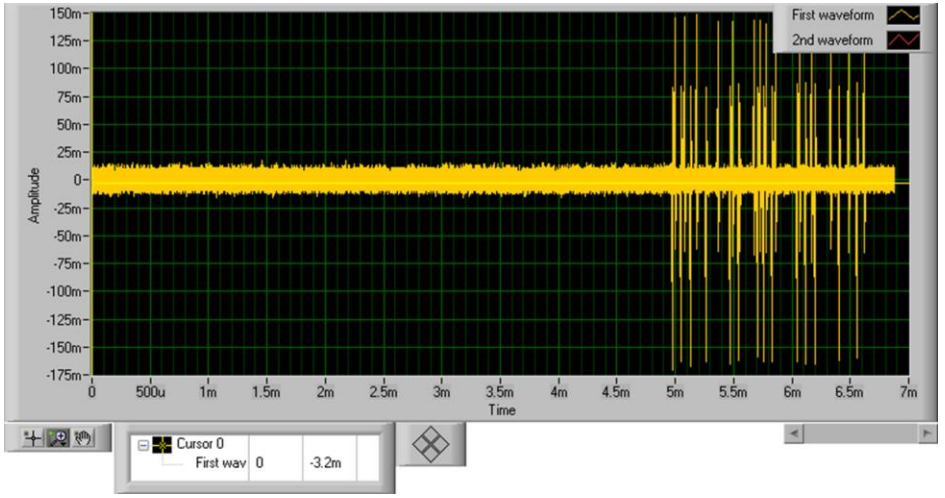
Note: Scale is 50mV/division to capture large transients

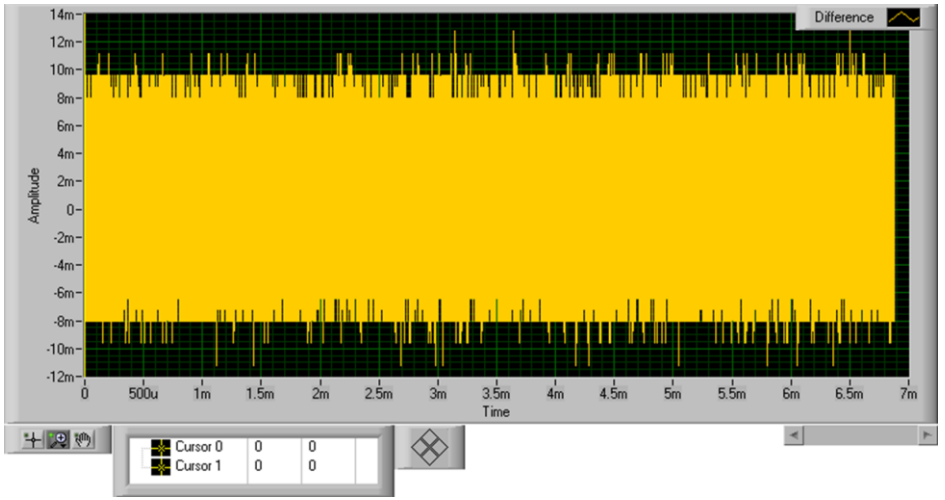
Common-Mode Acquisition Detail

- Predominant noise appears to be common-mode
  - The same signal is observed on both halves of the differential pair

Common-Mode Signal (Single Acquisition)

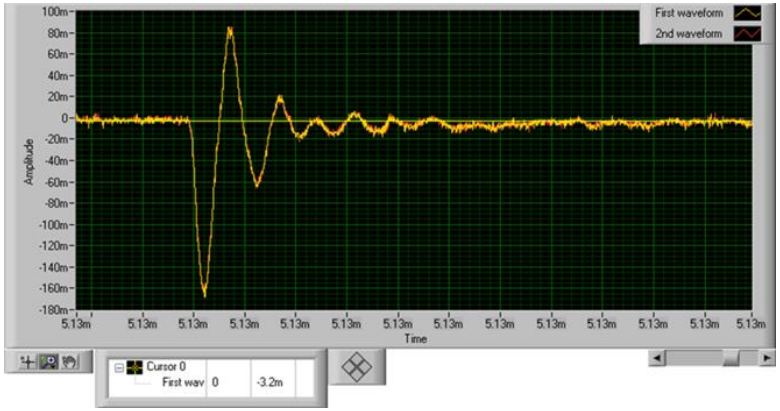
- One 7ms acquisition
  - Top is as-acquired positive & negative traces of one differential pair; ~300mV peak-to-peak
  - Bottom is calculated difference signal; ~25mV peak-to-peak

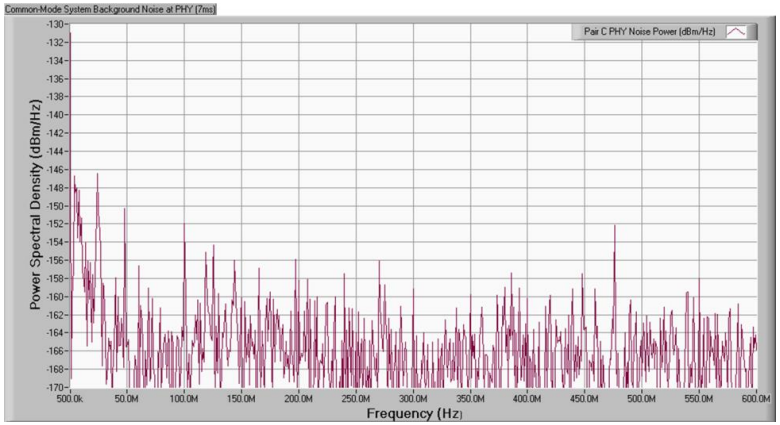




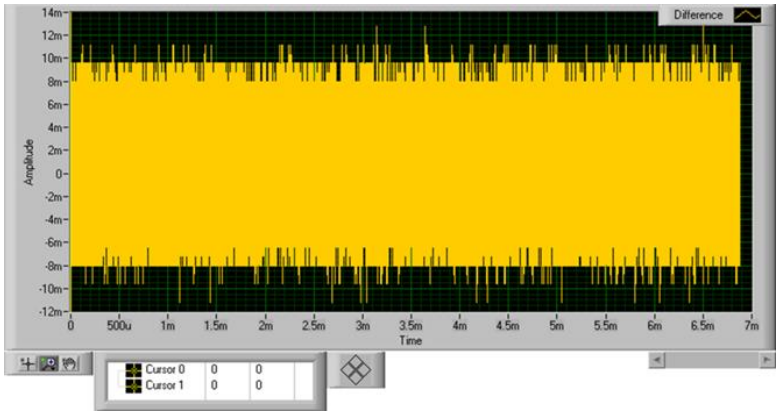
Common-mode and difference-mode noise Power Spectral Density

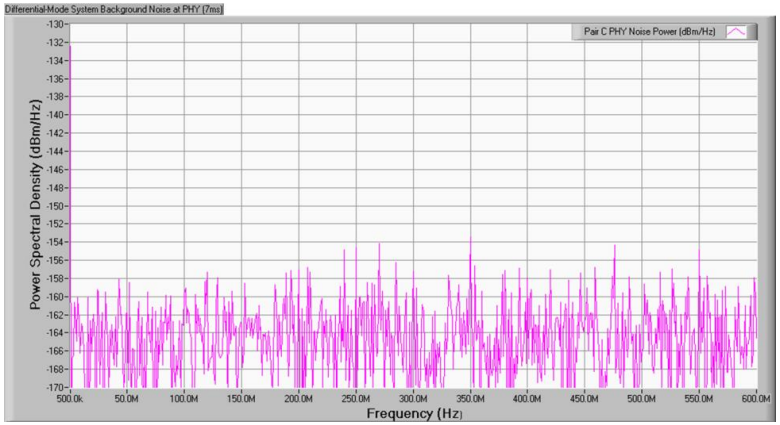
Common-mode: Total power from 500kHz to 600MHz = -74.3 dBm





Difference-mode: Total power from 500kHz to 600MHz = -75.0 dBm

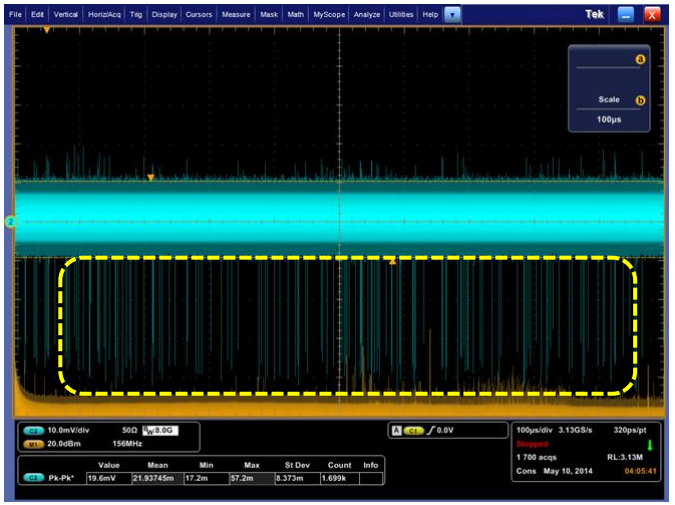




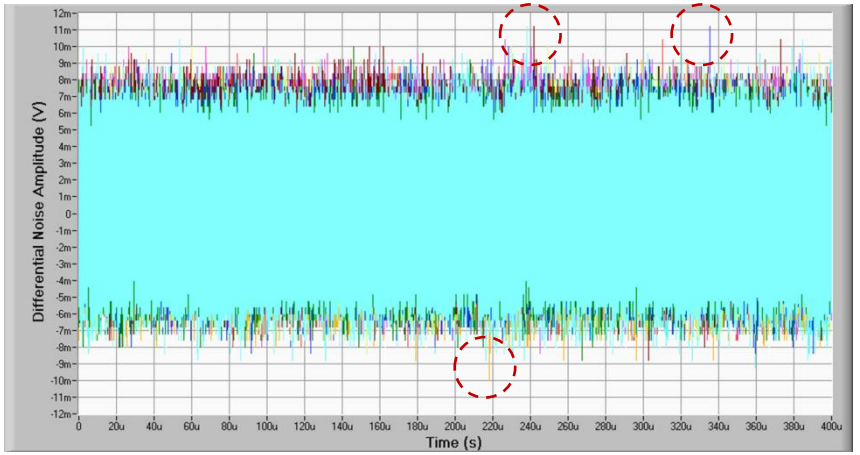
Note: Bandwidth (600MHz) is limited compared to later results

Representative Differential Probe Signal Acquisitions

- Short-term acquisition (~0.25h, 3.125Gs/s) shows some larger (~40mV peak) negative transients
  - Opportunity for further study
- Lower plot shows higher-resolution individual acquisitions (400us, 6.25Gs/s)
  - These acquisitions are used for the following analysis
  - Note: Observed peak amplitude is approximately negative 10mV to positive 11mV

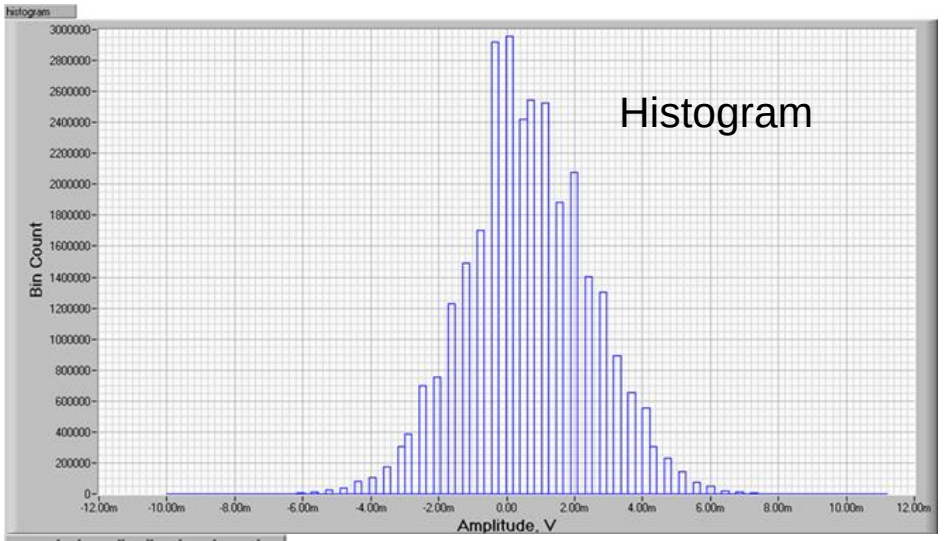


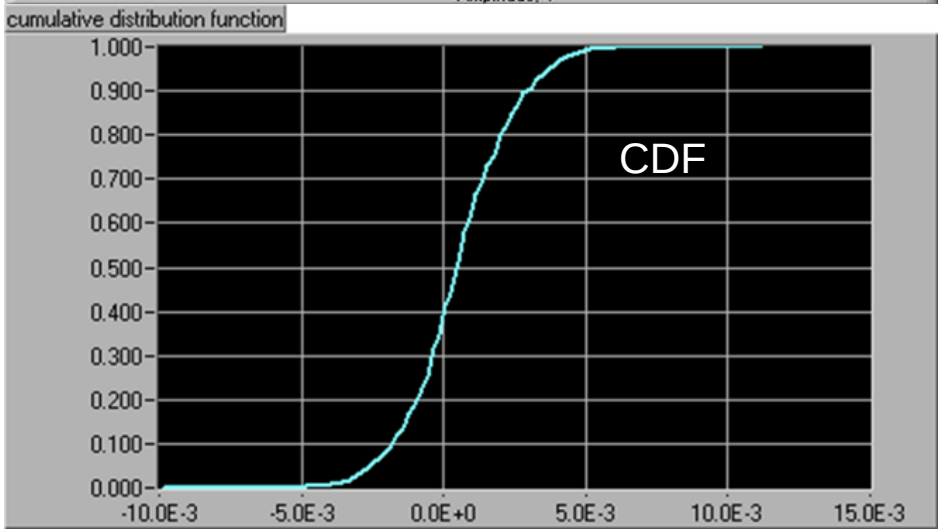
Note: Scale is 10mV/division



Differential noise characteristics

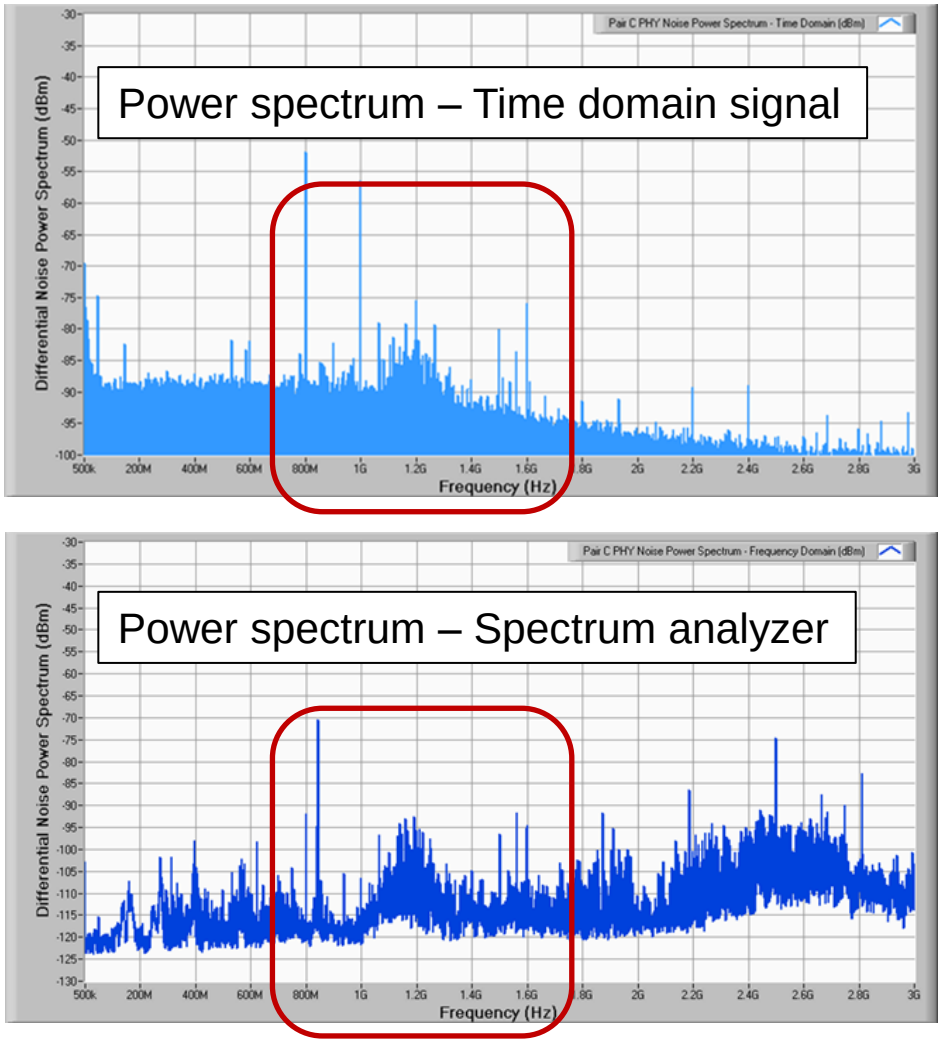
- Some representative noise descriptive statistics (12 acquisitions)
  - Population = 30M acquisitions
  - Minimum = -10.0mV
  - Maximum = 11.2mV
  - Mean = 6.26uV
  - Standard Deviation = 1.84mV





Time- and Frequency-Domain Power Spectrum Comparison

- Power spectrum plots of the same PHY port in the same server system
  - Top is FFT of an oscilloscope acquisition
  - Bottom is spectrum analyzer measurement obtained with noise floor extensions enabled
- Both show very similar relative spectral characteristics
  - Absolute calculated and measured power numbers are different (as expected)

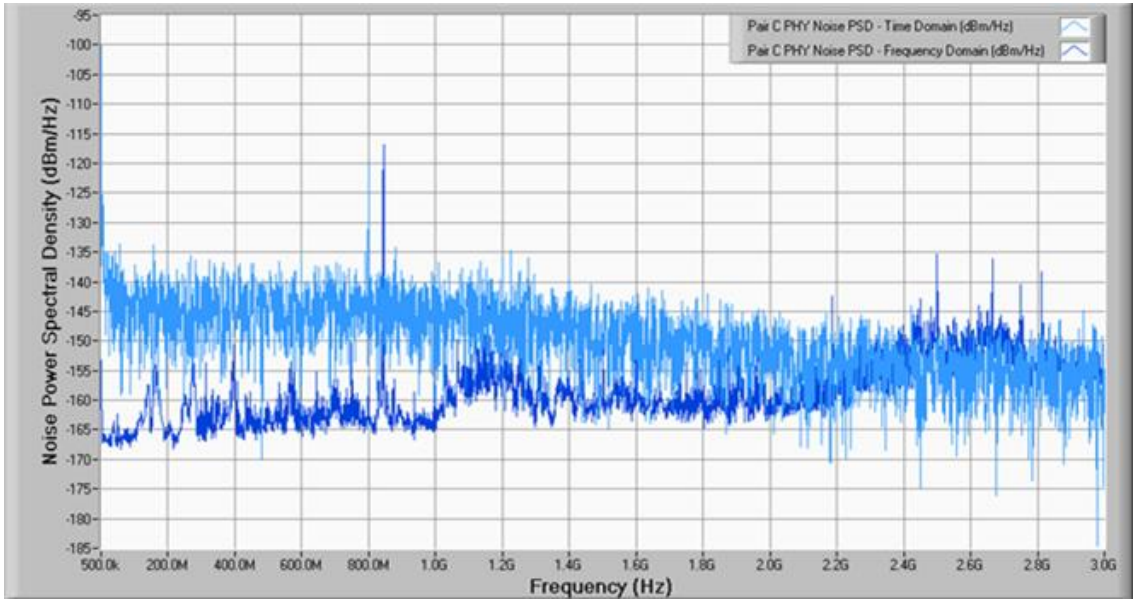


Noise Power Spectral Density

- Plot of system background noise PSD obtained from real-time signal acquisitions (light blue) and spectrum analyzer measurements (dark blue).
  - Differences are attributed several factors, including acquisition time (milliseconds vs. seconds) and known characteristics of the instrument signal acquisition front ends & architecture (bandwidth, noise floor, sensitivity, etc.)
- Average noise (real-time, all pairs)

  ~ -149.1 dBm/Hz
- Noise power (real-time, PSD integrated from 500kHz – 3GHz, all pairs)

  ~ -49.1 dBm



Parameter	Time-Domain FFT	Spectrum Analyzer
Average noise (dBm/Hz)	-149.14	-158.90
Noise power (dBm)	-49.08	-54.94

Conclusions

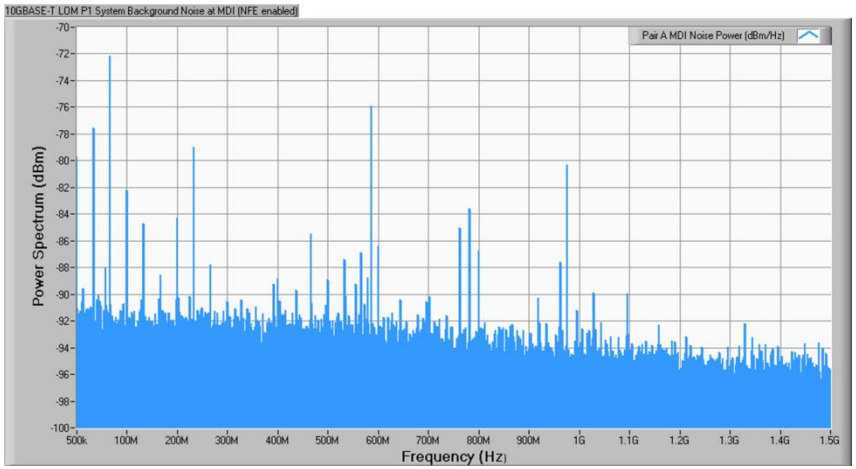
- Most “real-time” noise appears as common-mode to the PHY differential pair
  - Many short-duration, high-amplitude (440mV pk-pk) transients
- Difference-mode noise is significantly lower and appears to approximate AWGN
  - Are observed peak-to-peak values a concern for PHY performance?
- Noise power and noise power spectra are consistent with that obtained using frequency-domain measurement techniques
- For further study?
  - Better characterization of differential noise and observed noise transients

Thank You!

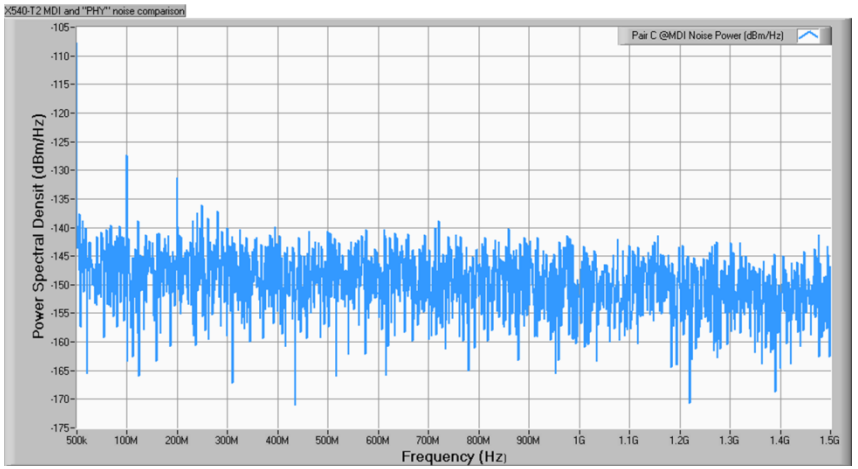
Questions?

Extended Acquisition Noise & Noise Power

Power Spectrum



Noise PSD



- Alternate SMA acquisition setting (6.25Gs/s over ~10ms)
  - Provides a wider bandwidth spectrum: 500kHz - 1.5GHz
- Calculated integrated noise power: ~-55.1 dBm/Hz

Additional Time Domain Spectra

- Overlaid power spectra from 12 time-domain acquisitions
  - Consistent noise is observed across multiple, independent acquisitions