Initial Measurements of System Background Noise in 10GBASE-T Systems

IEEE P802.3bq 40GBASE-T Task Force

Pete Cibula (Intel)
Dave Chalupsky (Intel)

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System Background Noise Measurement 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

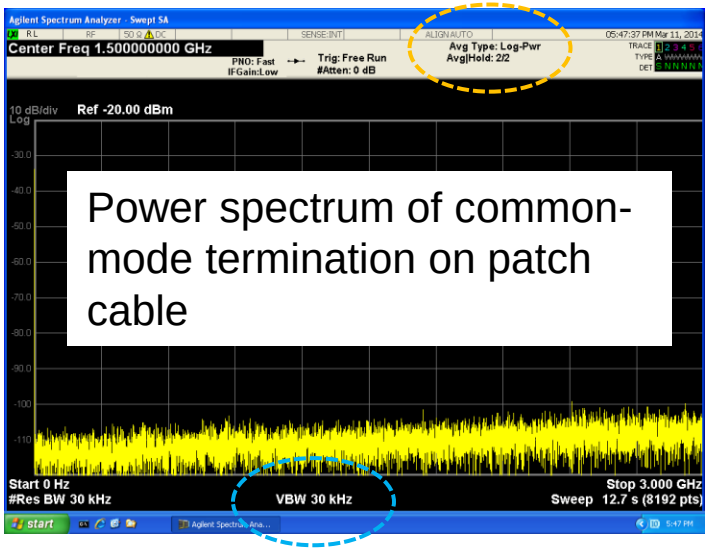
- Goals - This is a preliminary assessment intended to…
  - Describe a measurement methodology
  - Present initial measurement results based on that methodology
  - Stimulate further discussion of system noise measurement methodologies and ideas for further work in this area

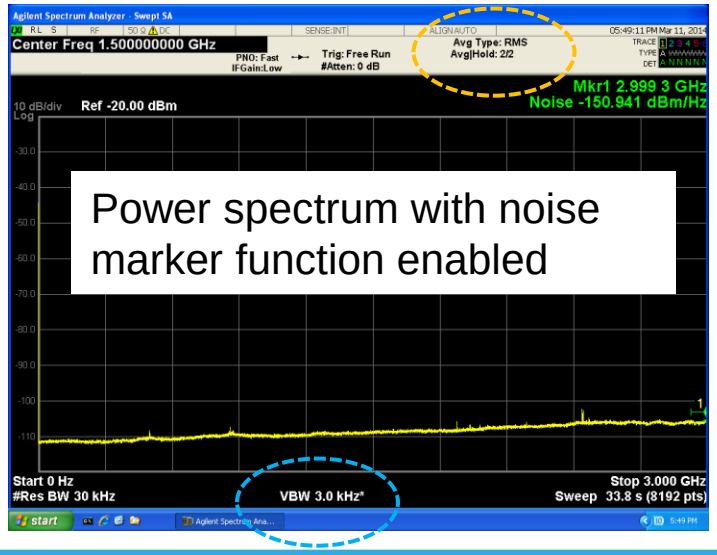
Methodology Overview

- Establish the measurement noise floor
  - PSD of noise from 500kHz to 3GHz at reference plane
    - Common-mode termination on short S/FTP RJ45 patch cord
- Characterize system background noise
  - PHY active but with all transmitters disabled
  - Measure system noise at MDI
    - RJ45 connection
  - Measure system noise at PHY
    - As close to PHY pins as practically possible
  - Subtract measurement noise floor to highlight system-specific background noise
- Compare measurements to identify system noise sources and evaluate MDI-based vs. PHY-based results

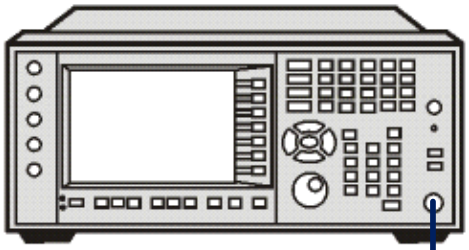
Instrument Configuration

- Spectrum analyzer measurement of system background differential noise
  - Instrument configuration – raw power spectrum
    - Span: 0Hz to 3GHz
    - Attenuation: 0dB
    - Detector: Average
    - RBW & VBW: 30kHz, 30kHz
    - Averaging type: Log Power
    - No. averages: 2x
  - Instrument configuration – noise marker spectrum (non-user-configurable differences only)
    - RBW & VBW: 30kHz, 3kHz
    - Averaging type: RMS
- Raw power spectrum may mask low-level stationary sources
  - Noise marker power spectrum used for all system noise measurements



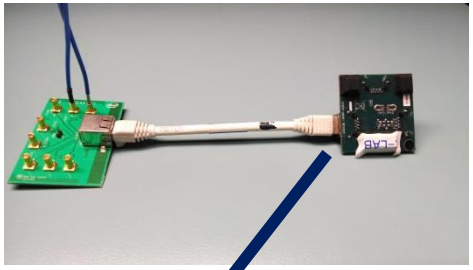


Measurement Setup (Noise Floor)



Coax SMA cables

Twisted pair patch cable



300kHz-3GHz Balun

2x SMA

RJ45/SMA Breakout

4 pairs 15cm CAT7

(+)

50 ohms

50 ohms

(-)

Load at each pair

Spectrum Analyzer

Single-ended to differential balun 300kHz – 3GHz

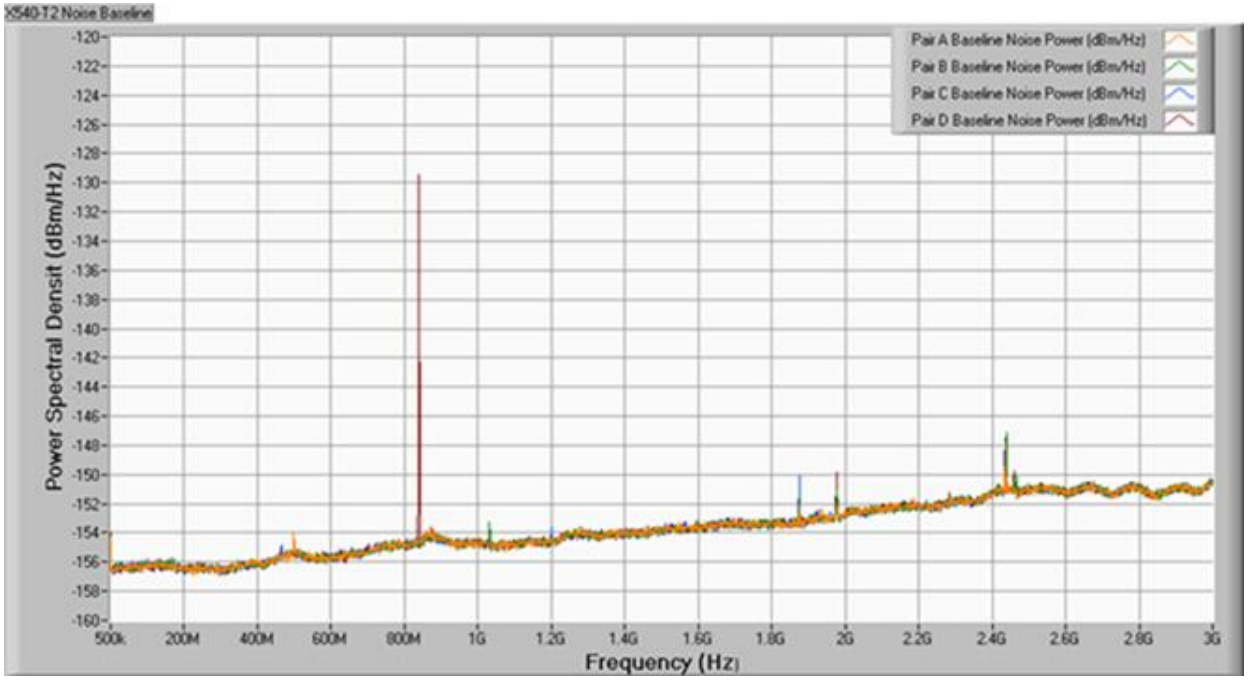
1x RJ45 to 8x 50ohm SMP breakout

Common-Mode Load Test Fixture

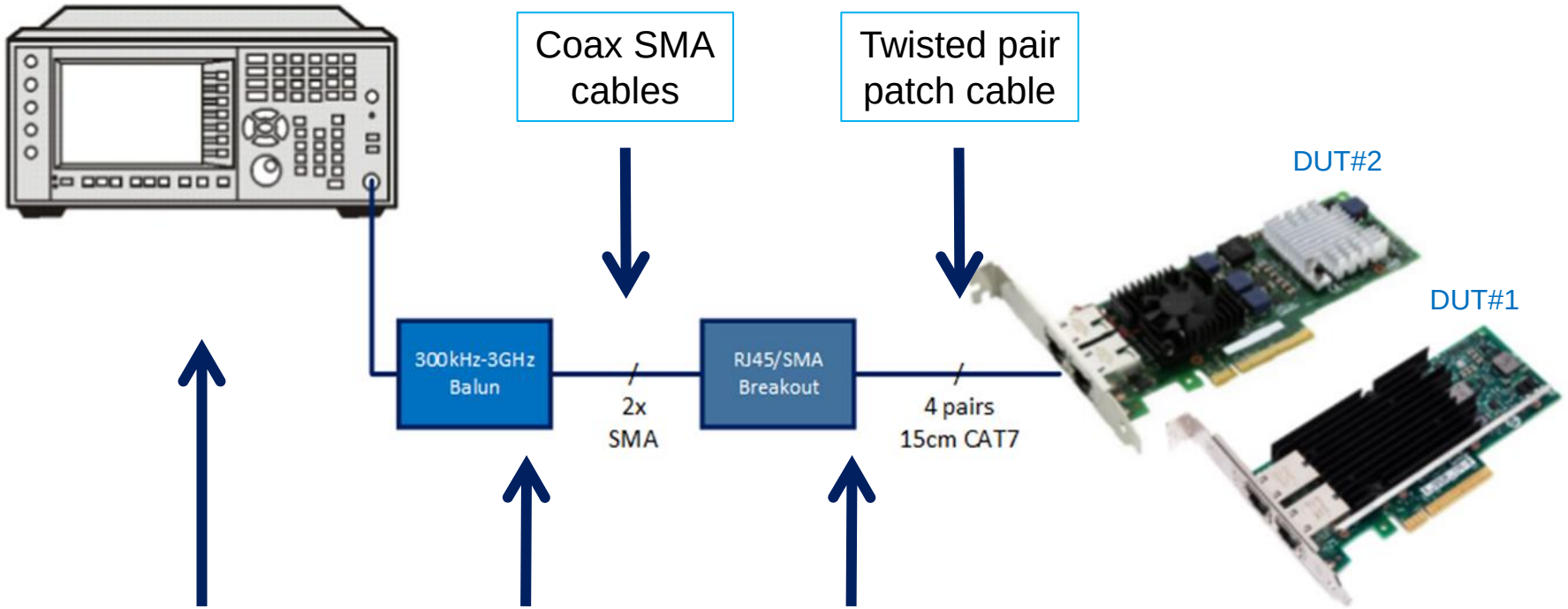
Noise Floor Measurement

- Noise floor as measured at the MDI interface (RJ45 plug) is consistent across all 4 pairs
  - Average noise is approximately -**153.7 dBm/Hz**
  - Noise power (PSD integrated from 500kHz – 3GHz) is approximately **-58.5 dBm**

Pair (Pins)	Average noise (dBm/Hz)	Noise Power (dBm)
A (1,2)	-153.67	-58.52
B (3,6)	-153.67	-58.52
C (4,5)	-153.67	-58.52
D (7,8)	-153.66	-58.52

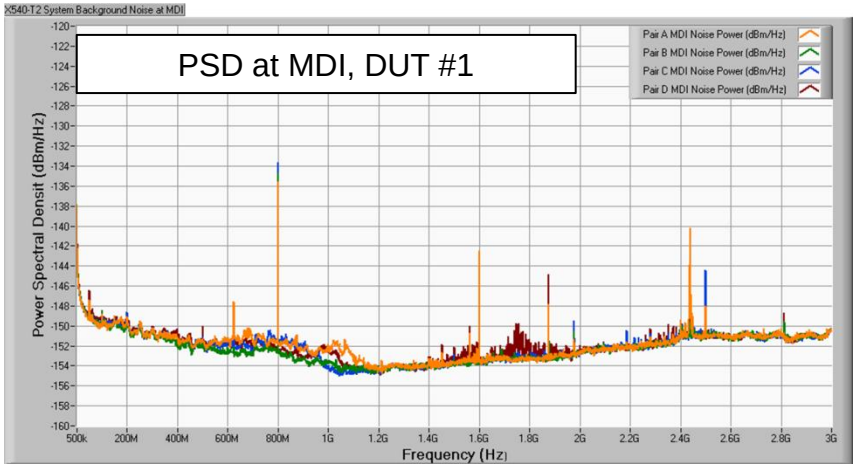


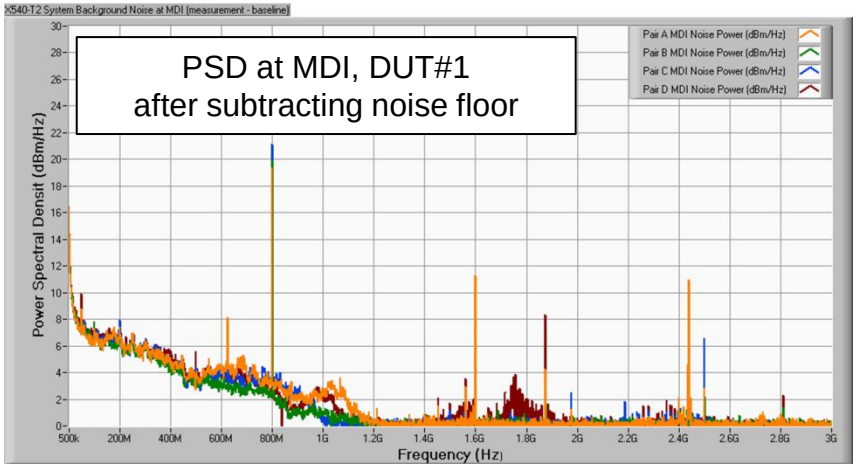
Measurement Setup (MDI)



MDI Measurements, DUT#1

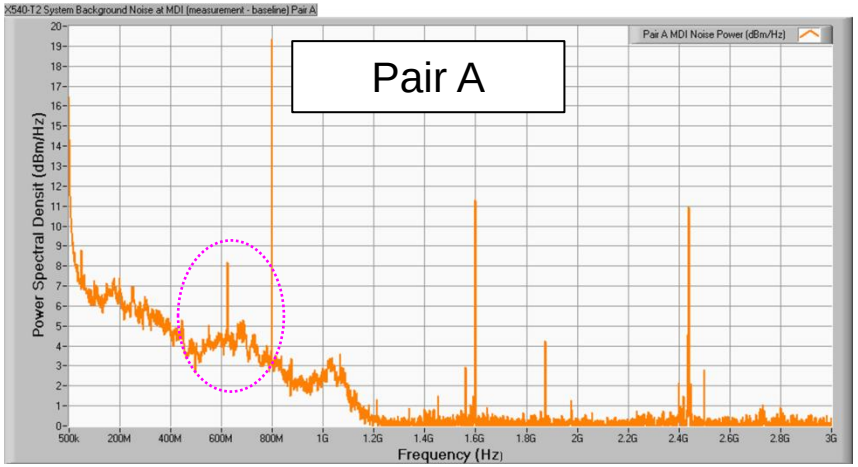
Pair (Pins)	Average noise (dBm/Hz)	Noise Power (dBm)
A (1,2)	-151.91	-56.78
B (3,6)	-152.24	-57.10
C (4,5)	-152.08	-56.92
D (7,8)	-151.92	-56.80

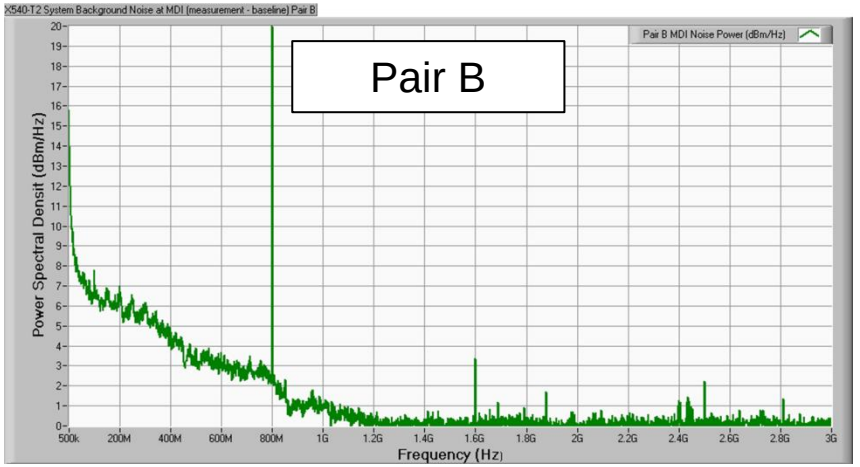


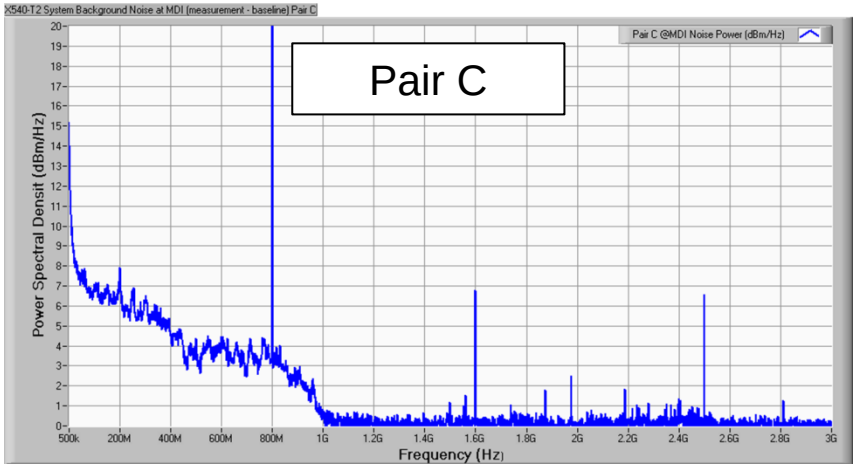


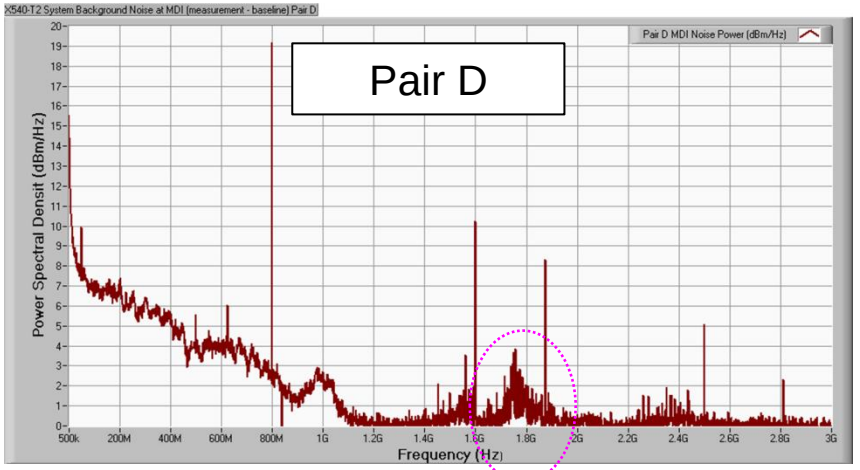
- System background noise for DUT #1 as measured at the MDI interface (RJ45 jack) displays the following characteristics:
  - Broadband source(s) from 500kHz to ~1.2GHz
  - Narrowband source (800MHz, 1.6GHz)
  - Narrowband source (625MHz, 1.875GHz, 2.5GHz)
- Average noise (all pairs) is ~ **-152.0 dBm/Hz**
- Noise power (PSD integrated from 500kHz – 3GHz, all pairs) is ~ **-56.9 dBm**
- Note that subtracting the noise floor gives a better picture of system background noise characteristics above the noise floor

MDI Noise Measurements, DUT#1
Per-pair noise above noise floor







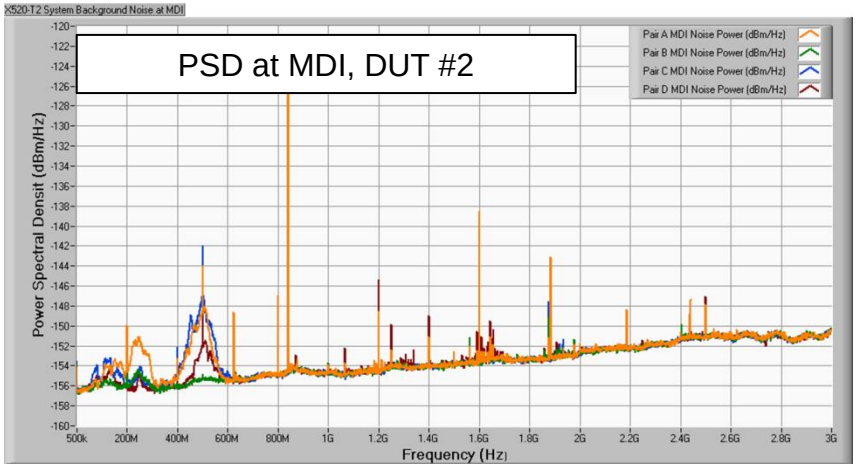


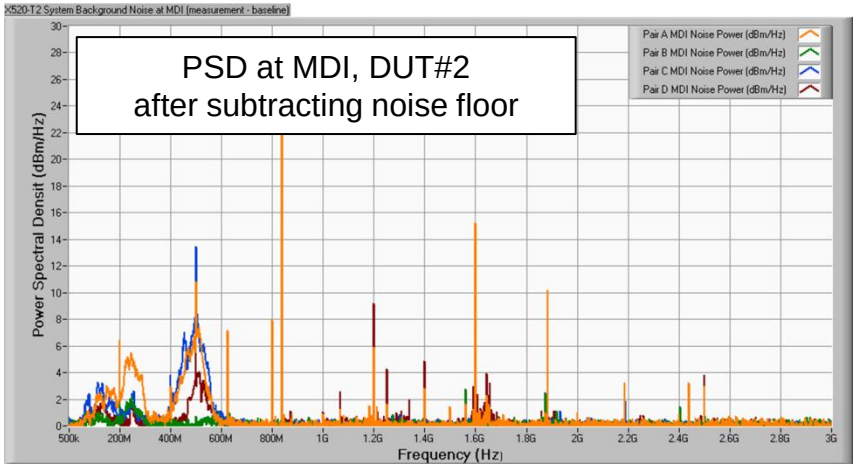
Some pairs appear to have unique sources (Pair A 600MHz; Pair D 1.6GHz - 2GHz)

MDI Measurements, DUT#2

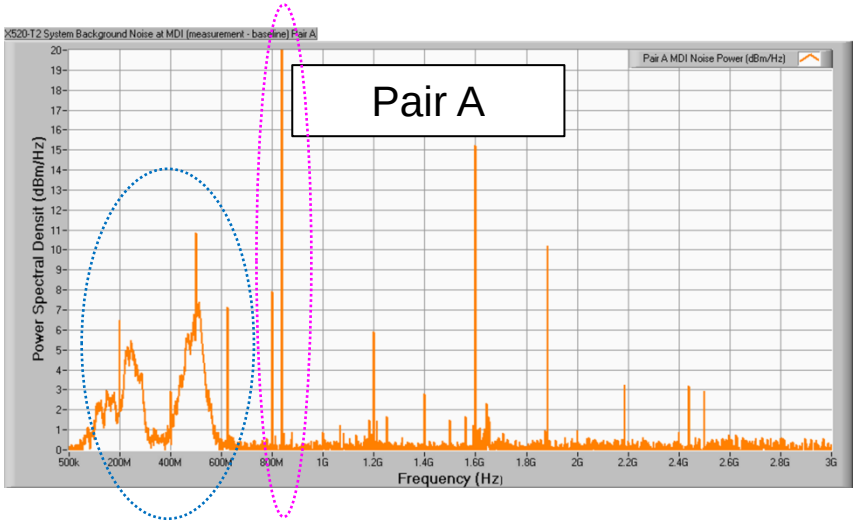
Pair (Pins)	Average noise (dBm/Hz)	Noise Power (dBm)
A (1,2)	-153.12	-57.34
B (3,6)	-153.57	-58.45
C (4,5)	-153.22	-58.07
D (7,8)	-153.44	-58.33

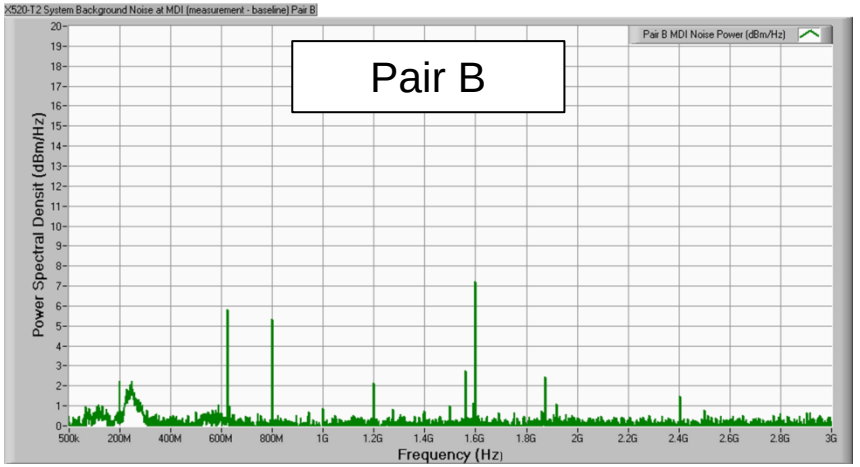
- System background noise for DUT #2 as measured at the MDI interface (RJ45 jack) displays the following characteristics:
  - Multiple source(s) from 500kHz to ~300MHz and between 400MHz and 600MHz
  - Unrelated (?) narrowband source at 500MHz
  - Narrowband source (800MHz, 1.6GHz)
  - Narrowband source (625MHz, 1.875GHz, 2.5GHz)
- Average noise (all pairs) is ~ **-153.4 dBm/Hz**
- Noise power (PSD integrated from 500kHz – 3GHz, all pairs) is ~ **-58.0 dBm**

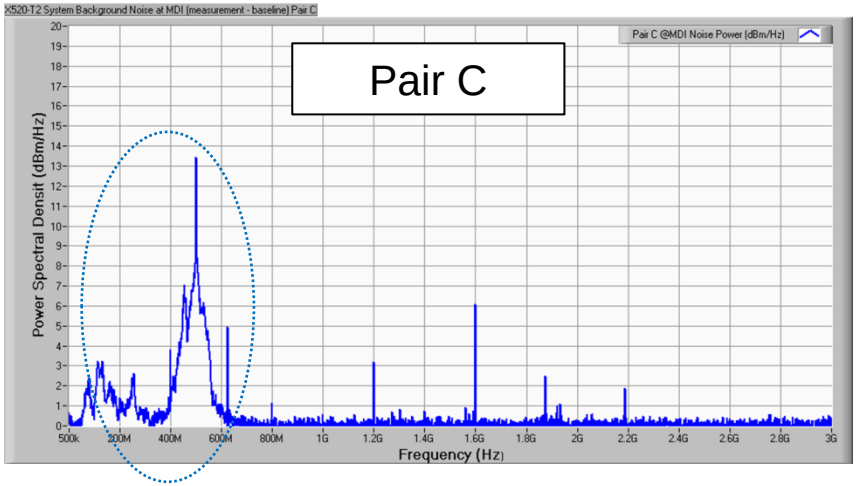


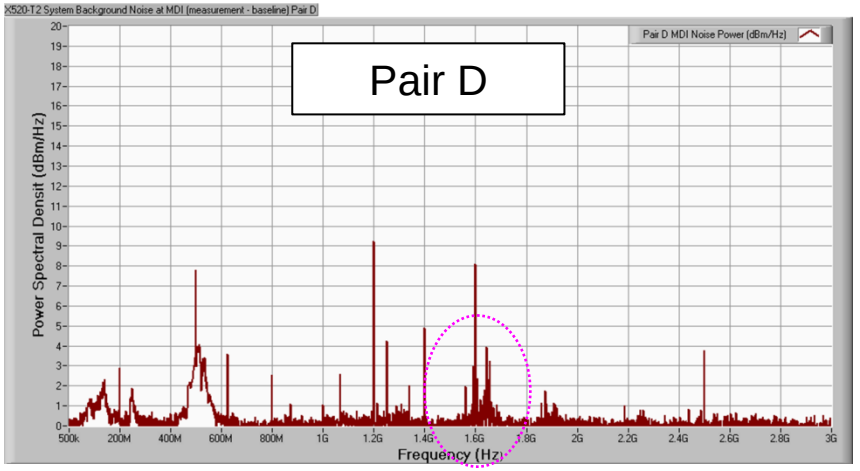


MDI Noise Measurements, DUT#2
Per-pair noise above noise floor



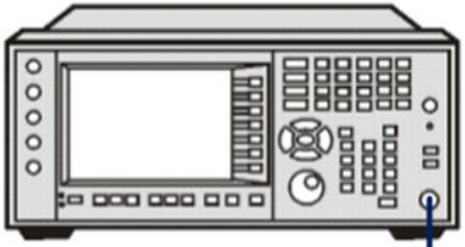






Unique sources (Pair A 839MHz; Pair D 1.5GHz – 1.7GHz); note more low frequency noise on A & C

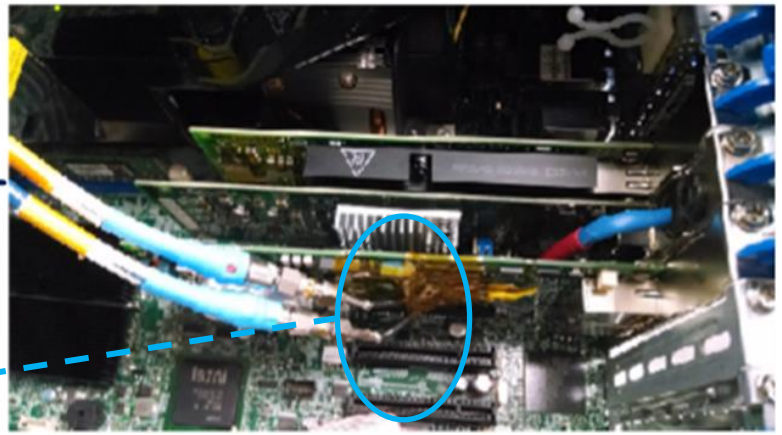
Measurement Setup (PHY)

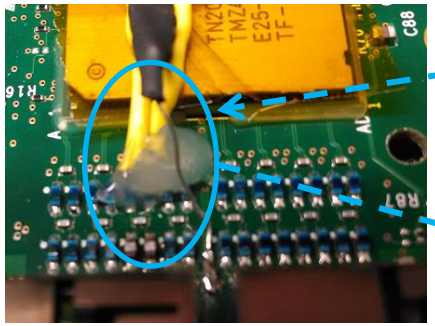


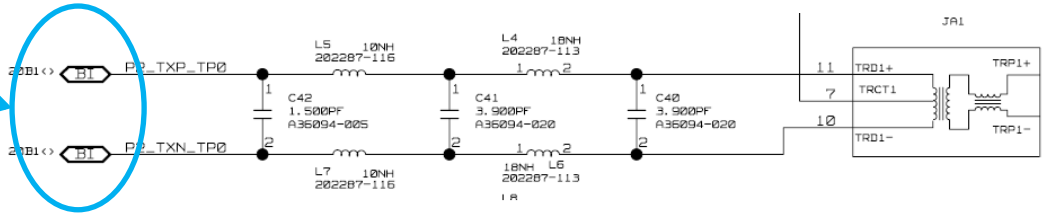
300kHz-3GHz Balun

2x SMA

DUT with all Tx disabled
Connections are post “cell phone” filter



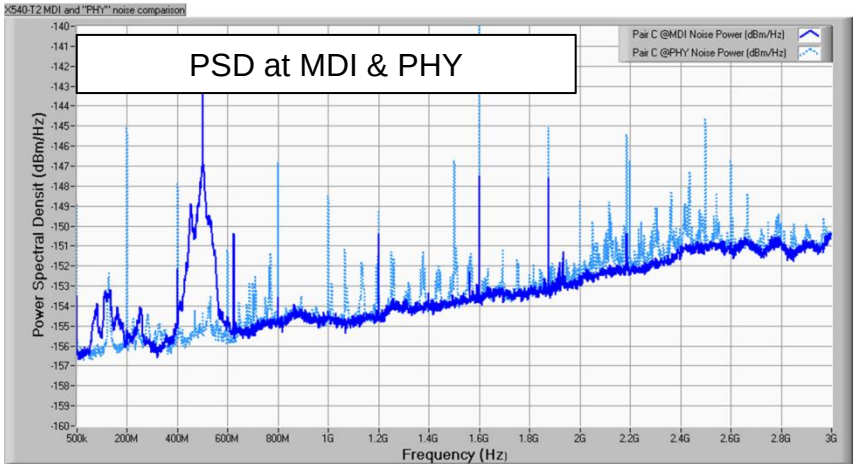


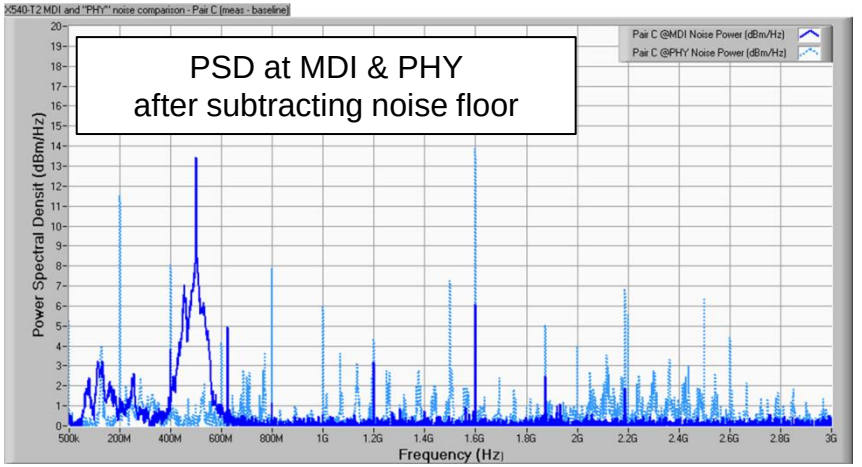


Noise Measurements, PHY vs MDI

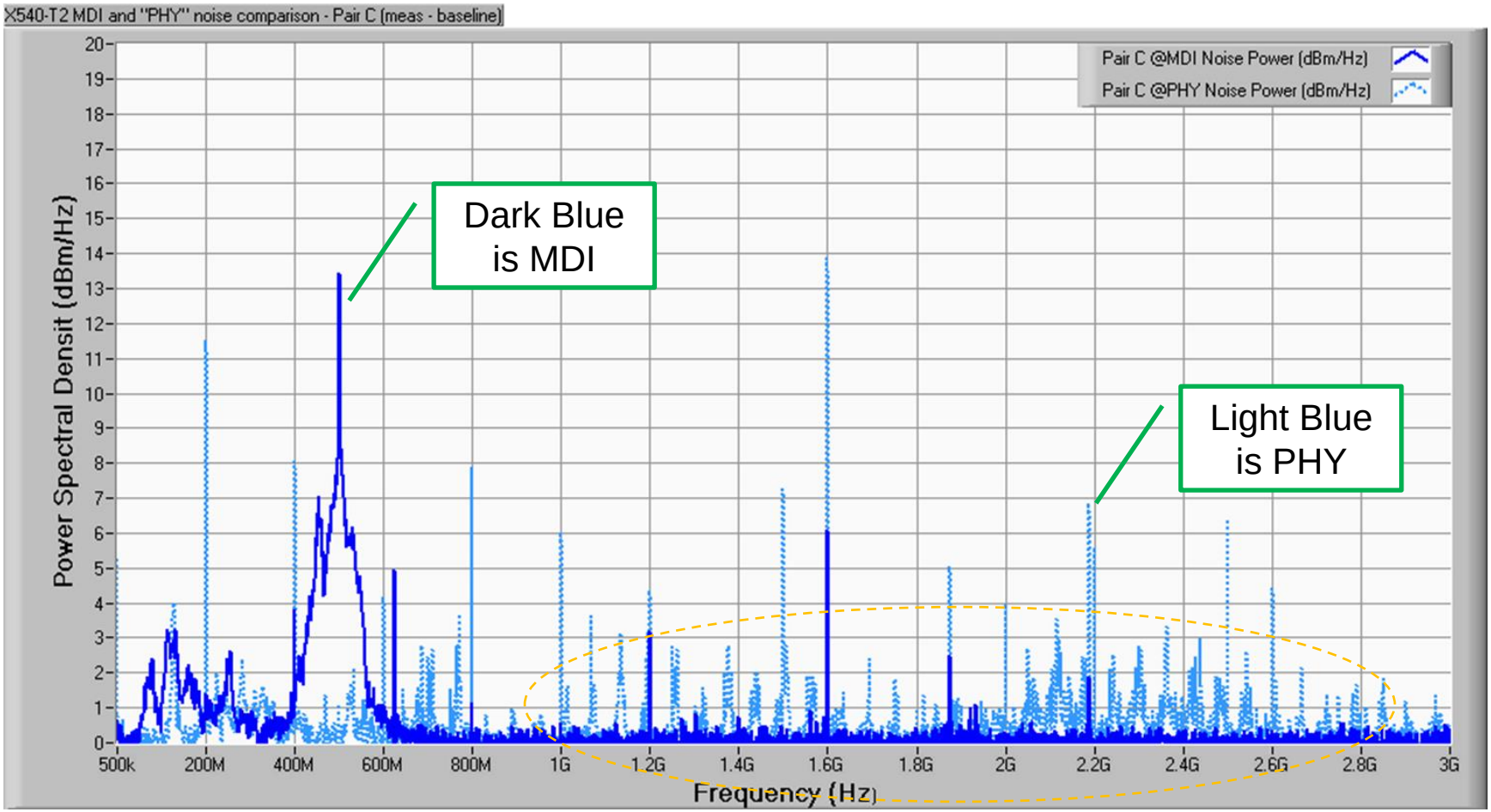
Pair (Pins)	Average noise (dBm/Hz)	Noise Power (dBm)
C (4,5) @ MDI	-153.22	-58.07
C (4,5) @ PHY	-153.19	-57.95

- Plots compare system background noise measured at the MDI with another measurement as close as practically possible to the PHY pins
  - It is difficult to instrument MDI trace pairs in real systems
  - Most PCB designs include few to no MDI trace debug features in in order to preserve signal integrity
  - Disclaimer: “Adapter ports *were* harmed in the measuring of this data”
- More high-frequency signals are present before the MDI filter (an expected result)
- However, average noise and total noise power are comparable





MDI & PHY power above noise floor



There is some obvious and expected overlap between measured noise
The PHY measurement includes more signals/sources above 1GHz

Results & Observations

- Average measured background noise for these two systems (10GBASE-T network adapters) is between
  -152dBm/Hz and -153dBm/Hz
- Average power for “easy” (at MDI) and “hard” (at PHY) measurements is about the same for the limited case presented.
  - Observed an expected “richer” spectrum – more peaks – before the on-board AFE “cell phone” filter.
- Specific background noise (assumed both broadband and stationary) varies across both MDI trace pairs and design implementations

Measurement	Average noise (dBm/Hz)	Noise Power (dBm)
DUT#1	-152.0	-56.9
DUT#2	-153.4	-58.0
Pair at MDI	-153.2	-58.1
Pair at PHY	-153.2	-58.0

Conclusions

- Measurements of two 10GBASE-T implementations indicate an average system background noise level of approximately -152 dBm/Hz to -153 dBm/Hz
  - This is in line with the -150 dBm/Hz level discussed in the January 14, 2014 P8023bq PHY Baseline Proposal ad hoc meeting minutes
- While average system background noise levels are comparable…
  - Specific background noise levels vary with implementation
  - Background noise levels may also vary across MDI pairs

Next Steps/Further Investigation

- Seeking feedback from the PHY Baseline Proposal ad hoc regarding these results
  - Implications for PHY design (power, complexity)
  - Relative importance of the additional information observed in PHY- vs. MDI-based measurements of system background noise power
    - If larger data sets are requested, MDI-based measurement is easier
- Improvements in measurement techniques?
  - Example: Use noise floor extension features (may be manufacturer-specific)
  - Time-domain, FFT based measurements to get non-stationary sources (power-on or other power delivery transients, noise from memory/storage transactions)
- Measurements in other systems?
  - 10GBASE-T server LAN-on-motherboard? Switches?

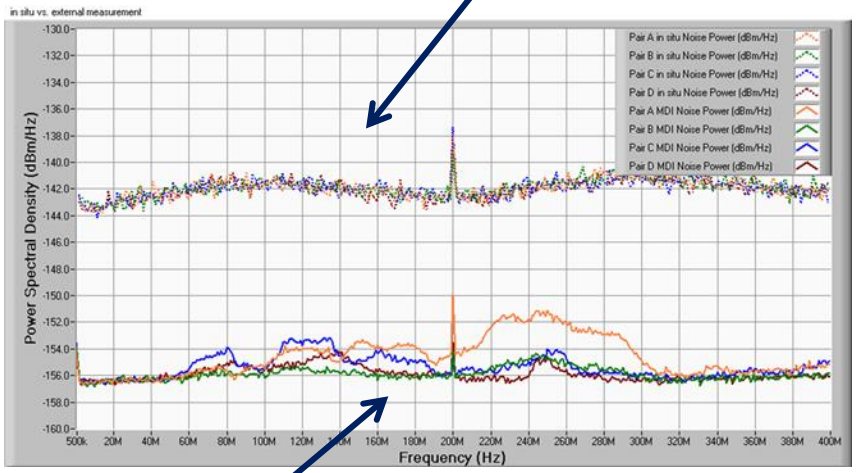
Thank You!

External vs. in-situ Method

- Recalling that the *in situ* tool is designed for basic system debug/manufacturing test, we can conclude that it gives an interesting starting point.

- Comparing earlier *in situ* results to results obtained with bench equipment, an external spectrum analyzer (or other test & measurement tool) is better suited for background noise characterization, especially for 40GBASE-T frequencies of interest.

in situ results from internal tool
PHY state unknown*



Spectrum analyzer at MDI
PHY in Tx disabled state

*in situ test results were presented in the Channel Modeling ad hoc meeting held January 23, 2014.
See cibula_3bq_channel_modeling_ad_hoc_initial_assessment_PCB_noise.pdf