Induced Common Mode Voltages on Shielded Twisted Pair Cabling

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Abstract

The P802.3bq Task Force recently chartered an ad hoc to investigate the receiver common mode noise rejection (Rx CMNR) test. The ad hoc identified several areas for discussion and investigation, including investigations along the lines of improving and augmenting the existing test.

This contribution presents measurements of common-mode voltages induced on shielded 30m channels using a modified cable clamp methodology. Results are provided for consideration by PHY implementers, and some suggestions for improvements to the existing test are provided for consideration by Task Force participants.

Background

- Twisted-pair Rx CMNR requirements have been previously reviewed with the P802.3bq Task Force and Task Force ad hocs
  - See cibula_3bq_02a_0714.pdf and feyh_3bqrxcmr_oct2214_40GBASET_EMC.pdf
- Some concerns and issues were identified with the 10GBASE-T test defined in 55.5.4.3 Common-mode noise rejection, including
  - Is the test appropriate for shielded implementations of interconnects that conform to 98.7.1 Cabling system characteristics?
  - Can impairments be introduced over the extended 2GHz range?

Goals

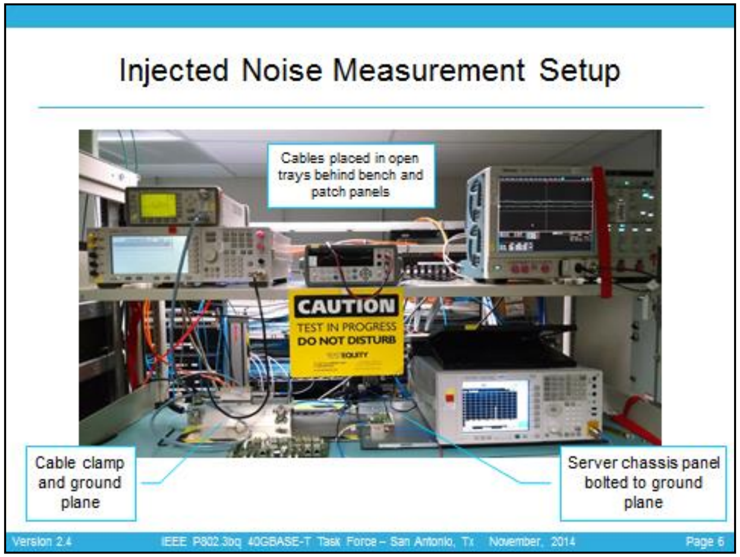
- Evaluate feasibility of the cable clamp methodology for screened shielded twisted pair (S/STP) cabling over an extended frequency range (80MHz to 2GHz)

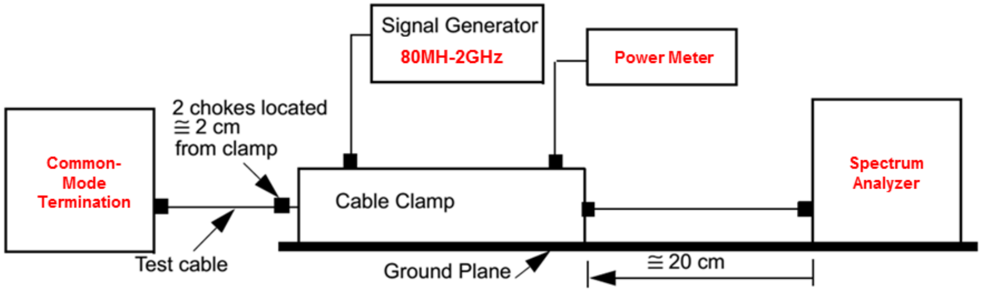
- Share some modifications to the receiver common-mode noise rejection (Rx CMNR) test referenced in Subclause 55.5.4.3 (and by extension, Subclause 40.6.1.3.3)

- Present measurements of induced common mode voltages on S/STP cabling

Measurement Setup

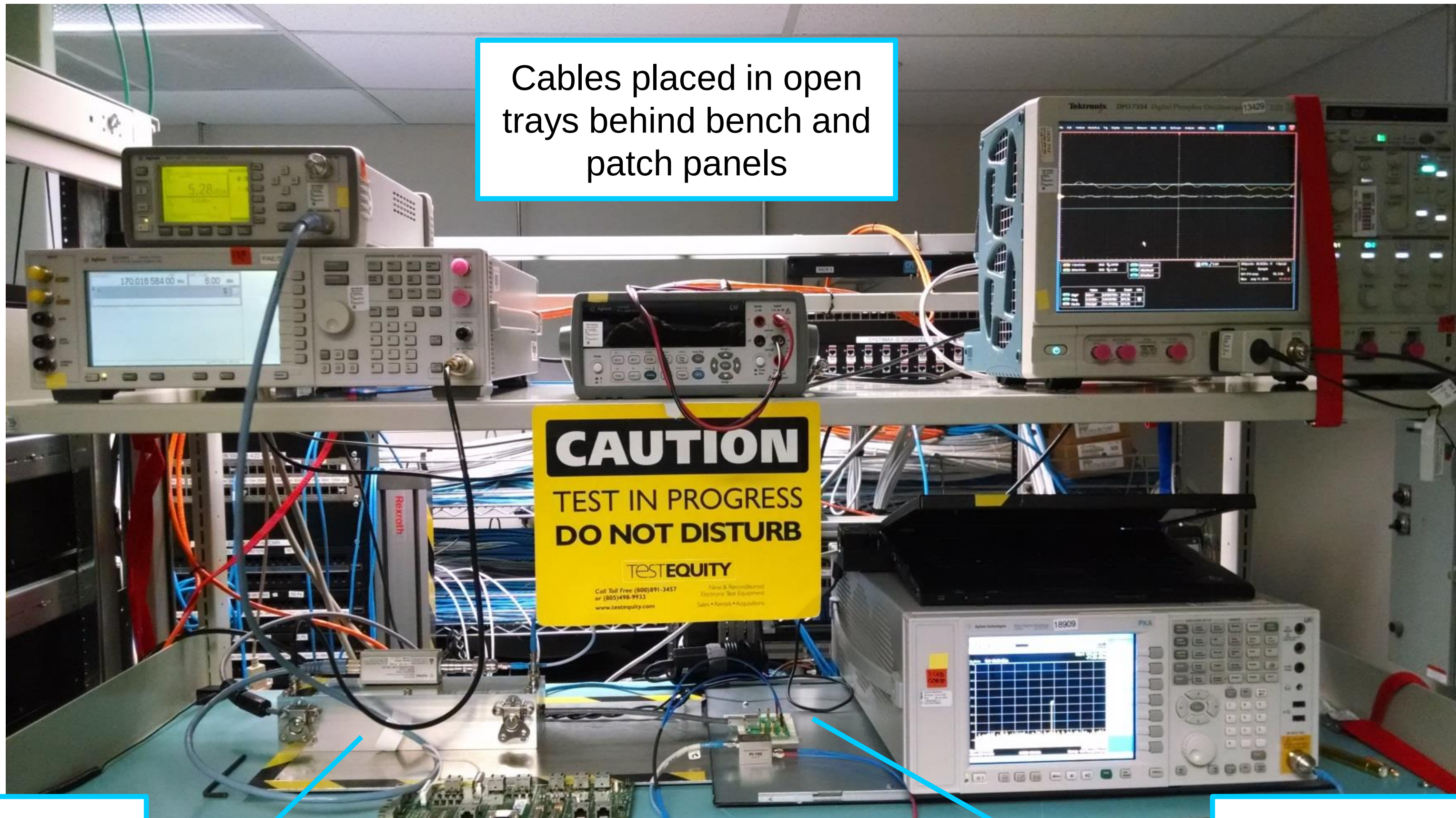
- Same setup used in previous contributions on common-mode and system background noise
  - MDI measurement point is a balun-connected RJ45 modular jack breakout
  - PHY measurement point is on the PHY side of a 10GBASE-T ICM with Tx disabled



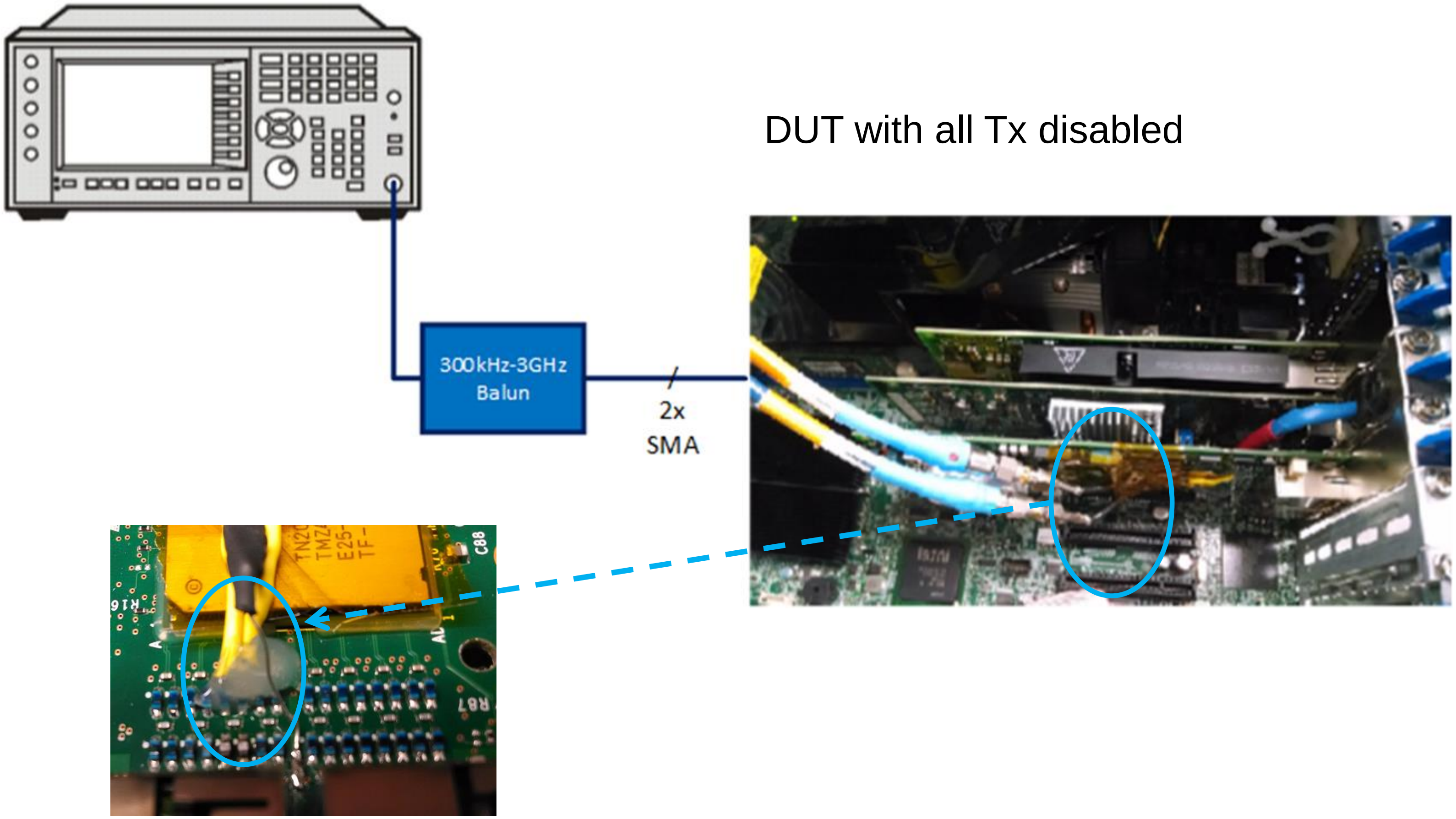


A representative 10GBASE-T Receiver Common-mode rejection test

A Clause 55.5.4.3 CMNR Setup (Characterization configuration)



Measurement Setup (PHY pins)

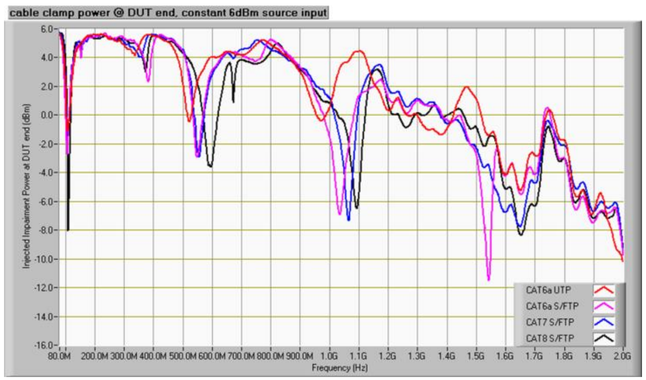


Basic Measurement Flow

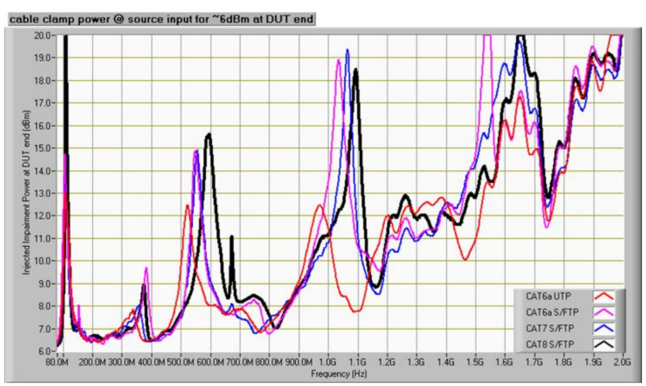
- Prepare 2-connector, 30m channels of selected cable types
  - CAT6a UTP, CAT6a S/FTP, CAT7 S/FTP, CAT8 S/FTP
- Measure clamp (with cable) response to a fixed +6dBm source input over the frequency range 80MHz to 2GHz
  - 1604 points, 500ms dwell/point
- Calculate an appropriate source power correction factor to create an ~6dBm signal to present to the DUT
- Using the corrected source power, measure the injected noise frequency & power at each signal pair
  - MDI for all channels, PHY for CAT6A UTP and CAT8 S/FTP
  - 2s dwell/point for spectrum analyzer signal acquisition
- “Rinse and repeat”

Can we get 6dBm over the extended frequency range?

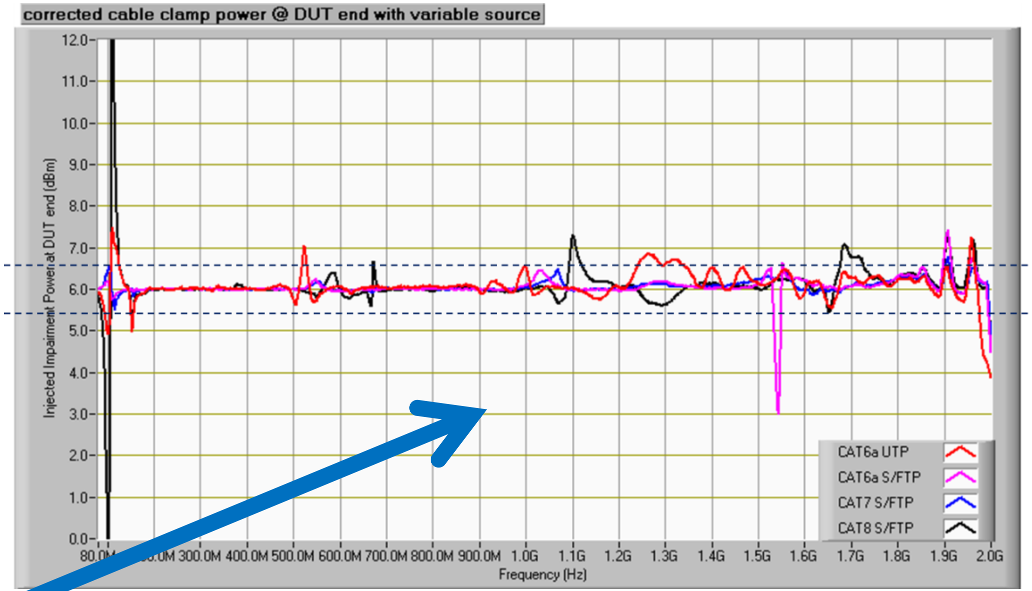
Response to fixed +6dBm source



Calculate source power for +6dBm at "DUT end"



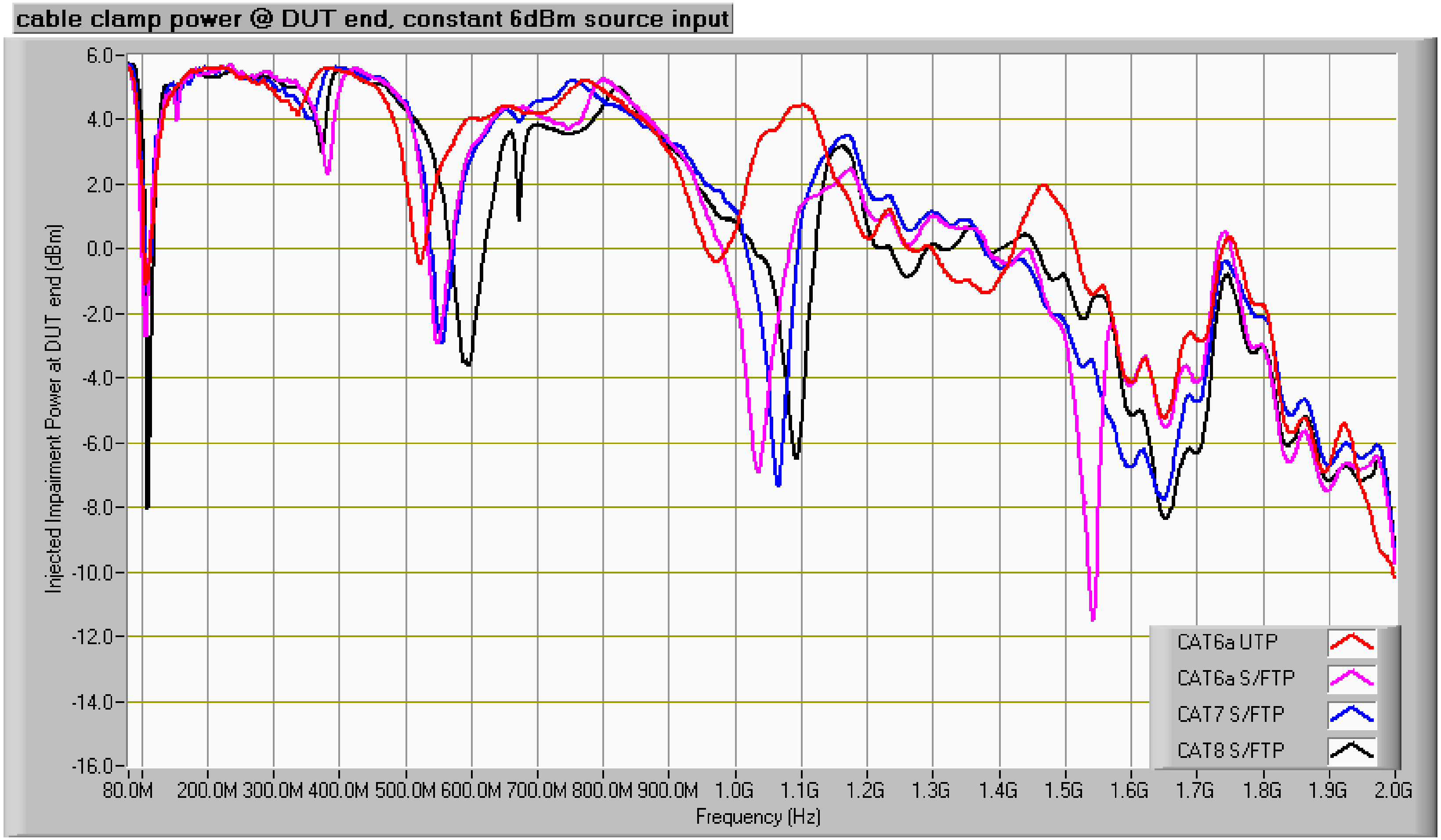
Noise to DUT
Ideally 6dBm +/- 7.5%



…a qualified "Yes"

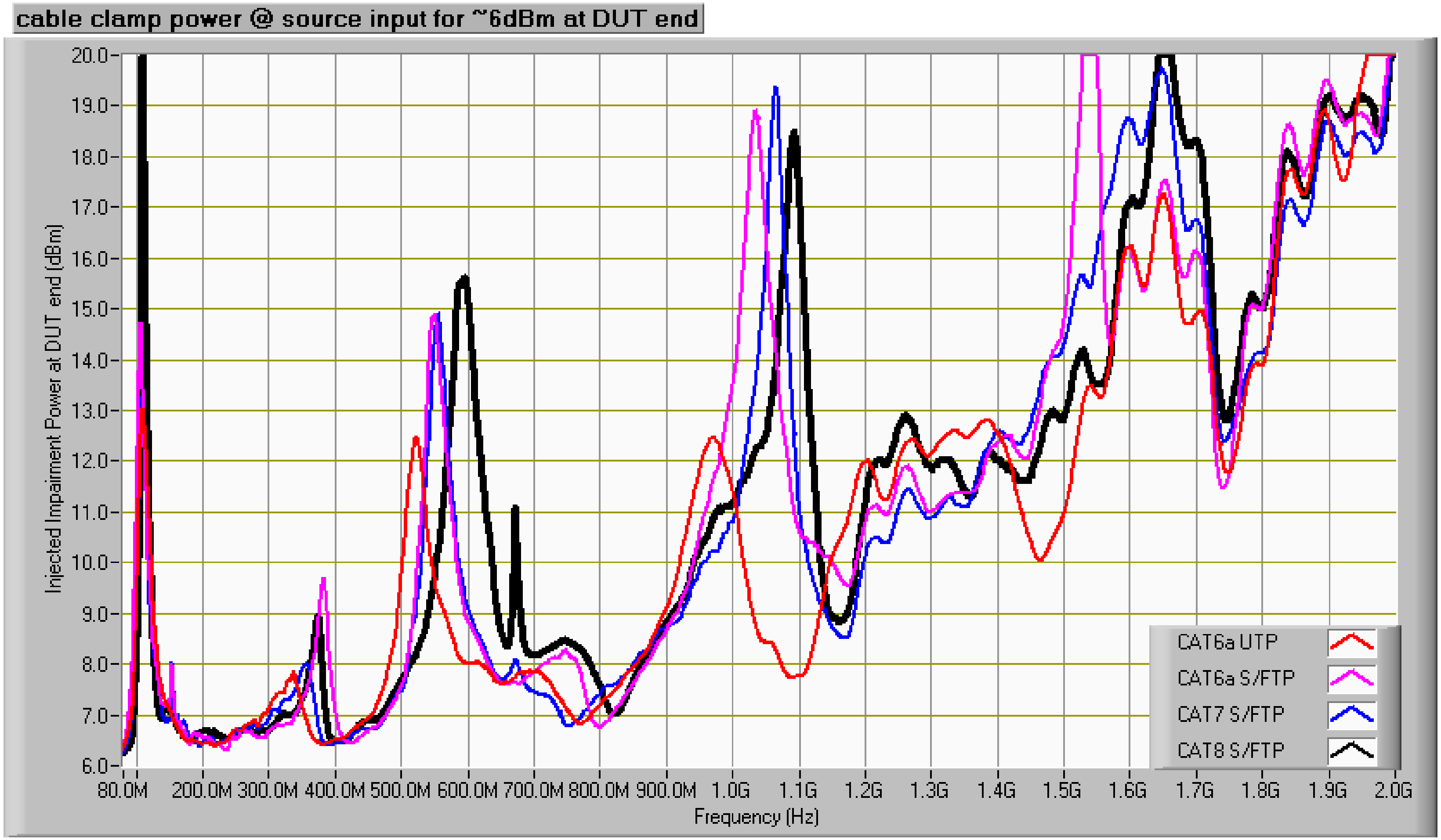
Assumes improved calibration techniques

Uncorrected responses to a fixed +6dBm source



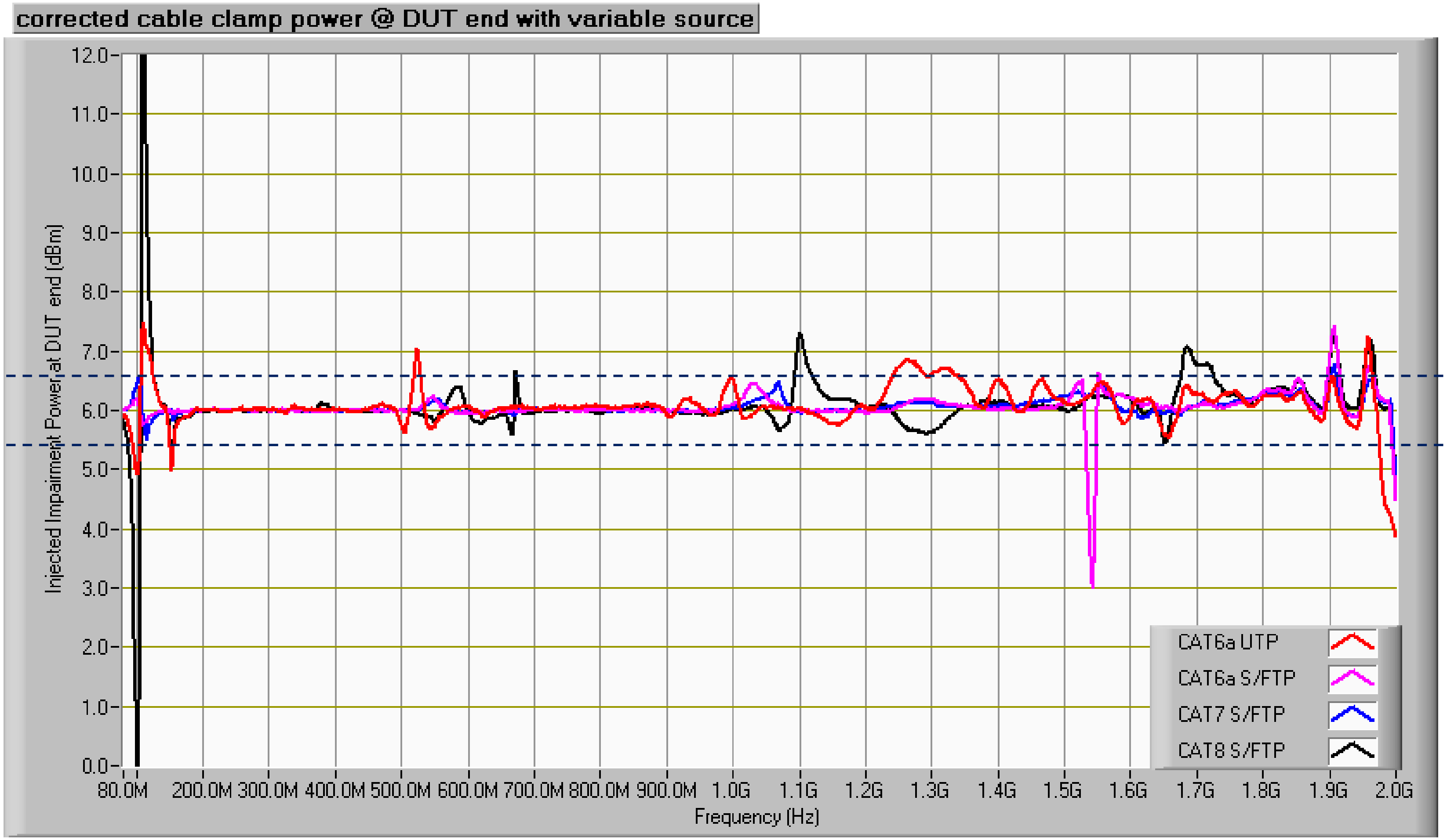
All cable types show roughly similar responses over the measured frequency band.
Some notable differences in unshielded vs. shielded types above ~1GHz.

Required source power for +6dBm to DUT



Signal generator used is limited to a +20dBm output.
A broadband amplifier could be used to provide additional gain if desired.

Corrected response obtained using calculated source power (~6dBm signal)



Dashed lines show +/- 7.5% limits described in Annex 40B.

CAT8 S/FTP result show some anomalies from calibrating with a resistive vs. reactive load.

Key Points So Far

- The cable clamp methodology can be extended to 2GHz with appropriate modifications (and attention to detail!)
  - The conclusion presented in 1998 - pursue the coaxial clamp method – appears to hold for 2014.

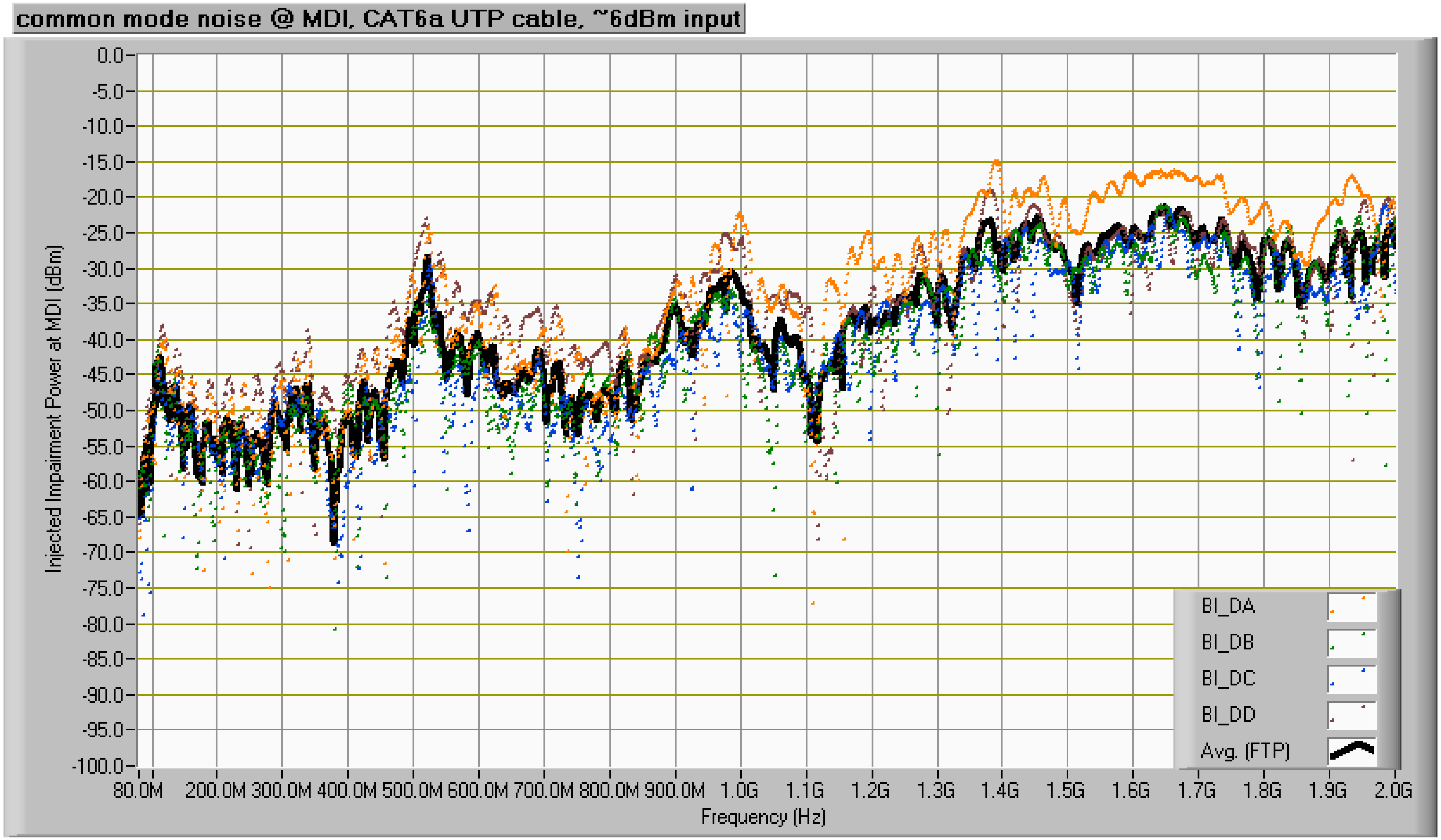
- While specific discussion of any improvements is a task for the Rx CMNR ad hoc, some general observations include:
  - Improved fixturing (clamp for larger-diameter cable, careful cable alignment in the clamp)
  - Use improved instrumentation (power meters, spectrum analyzers) – more common and not perceived as “exotic”
  - Calibrate with appropriate loads (disabled transceivers?)
  - *In general, work to minimize the “poor reproducibility we’ve come to accept in the black art of EMC testing”*

Injected Noise Measurements

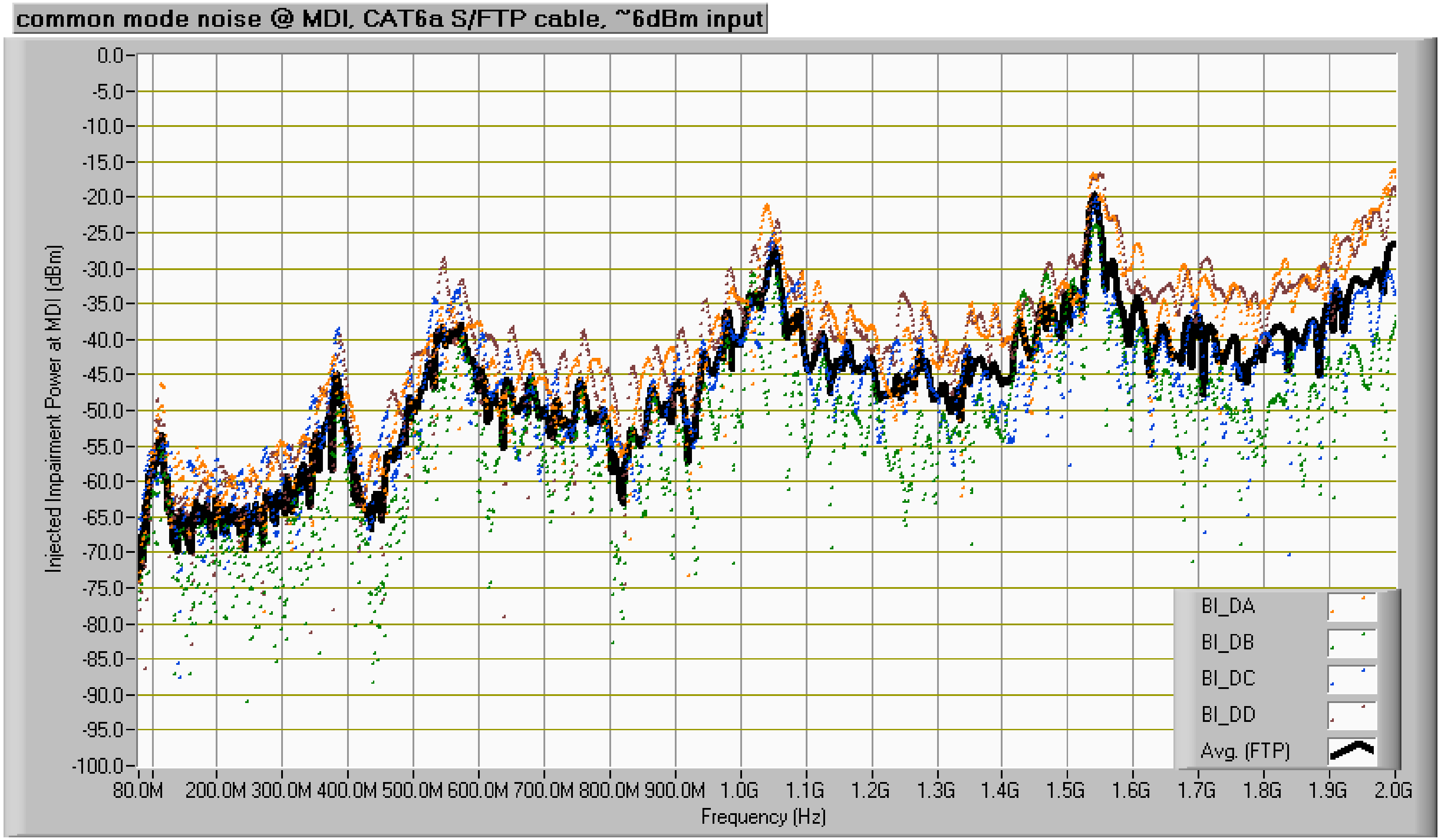
- The following plots (9 total) show injected noise measured at the MDI (4 cable types) and at a 10GBASE-T PHY in a server system (2 cable types)

- Results for the 4 cable pairs are averaged to facilitate a few high-level comparisons
  - Noise at the MDI for all cable types
  - CAT6a UTP vs. CAT8 S/FTP at MDI
  - CAT6a UTP vs. CAT8 S/FTP at the PHY

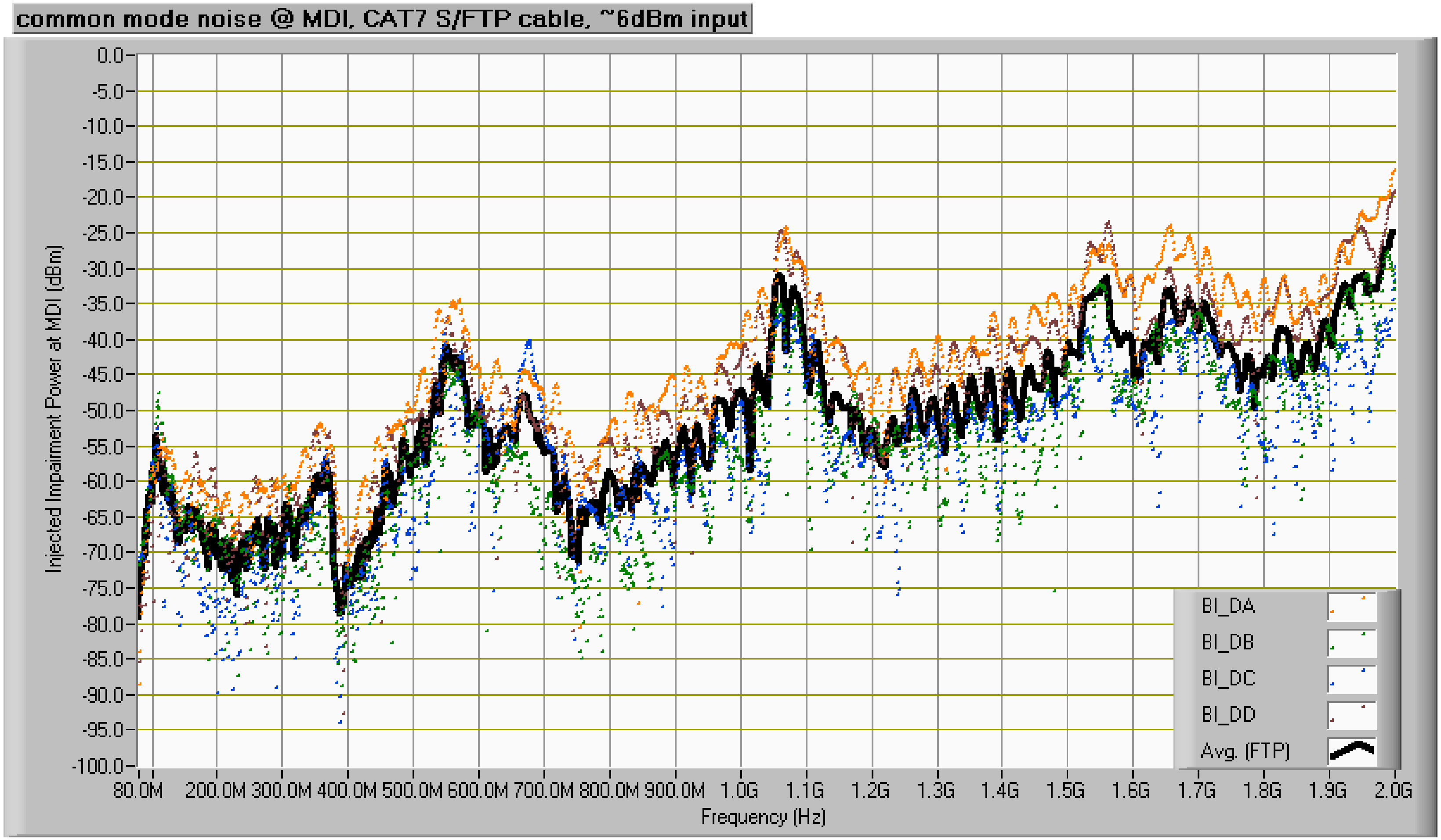
CAT6a UTP (MDI)



CAT6a S/FTP (MDI)

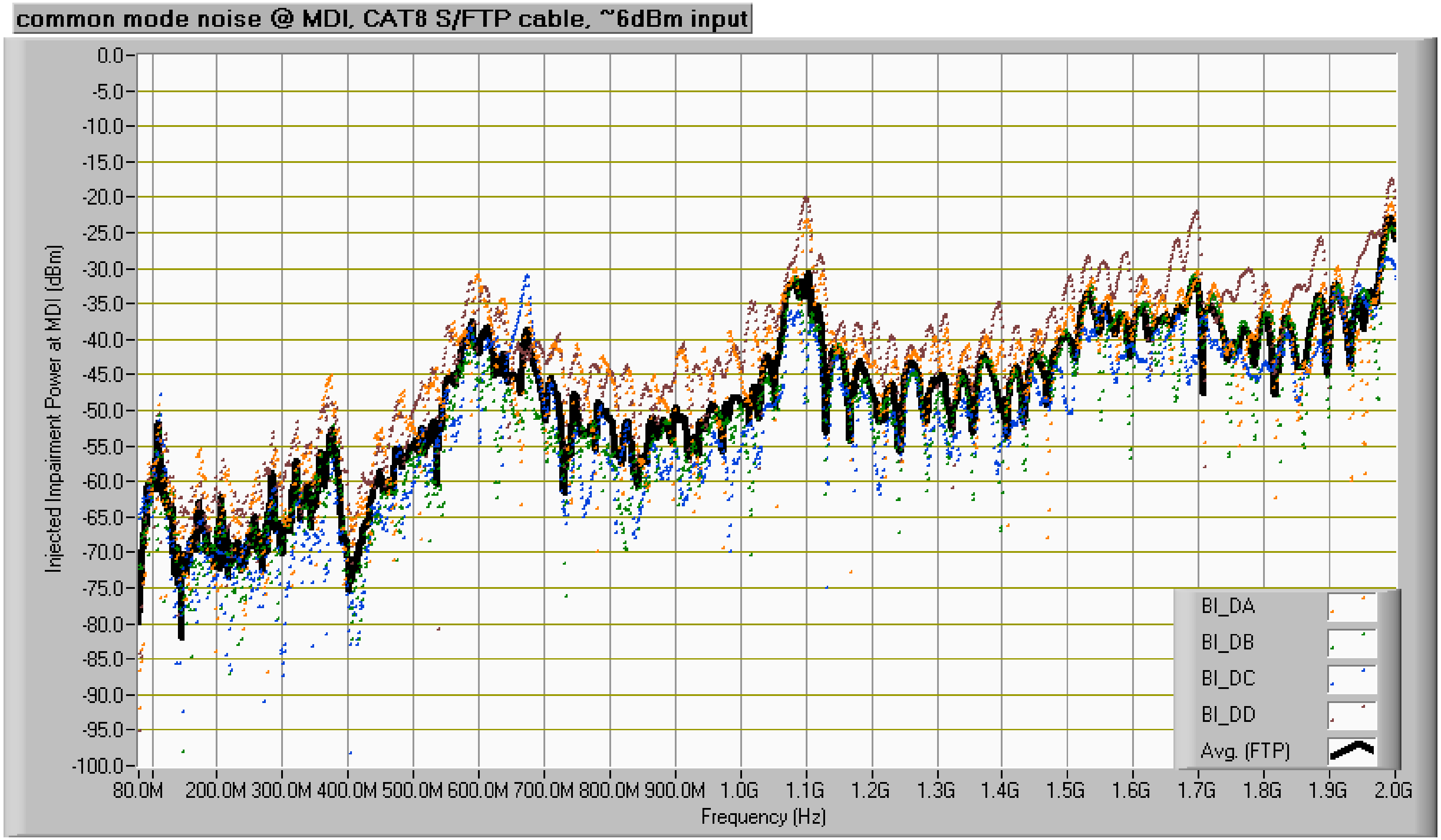


CAT7 S/FTP



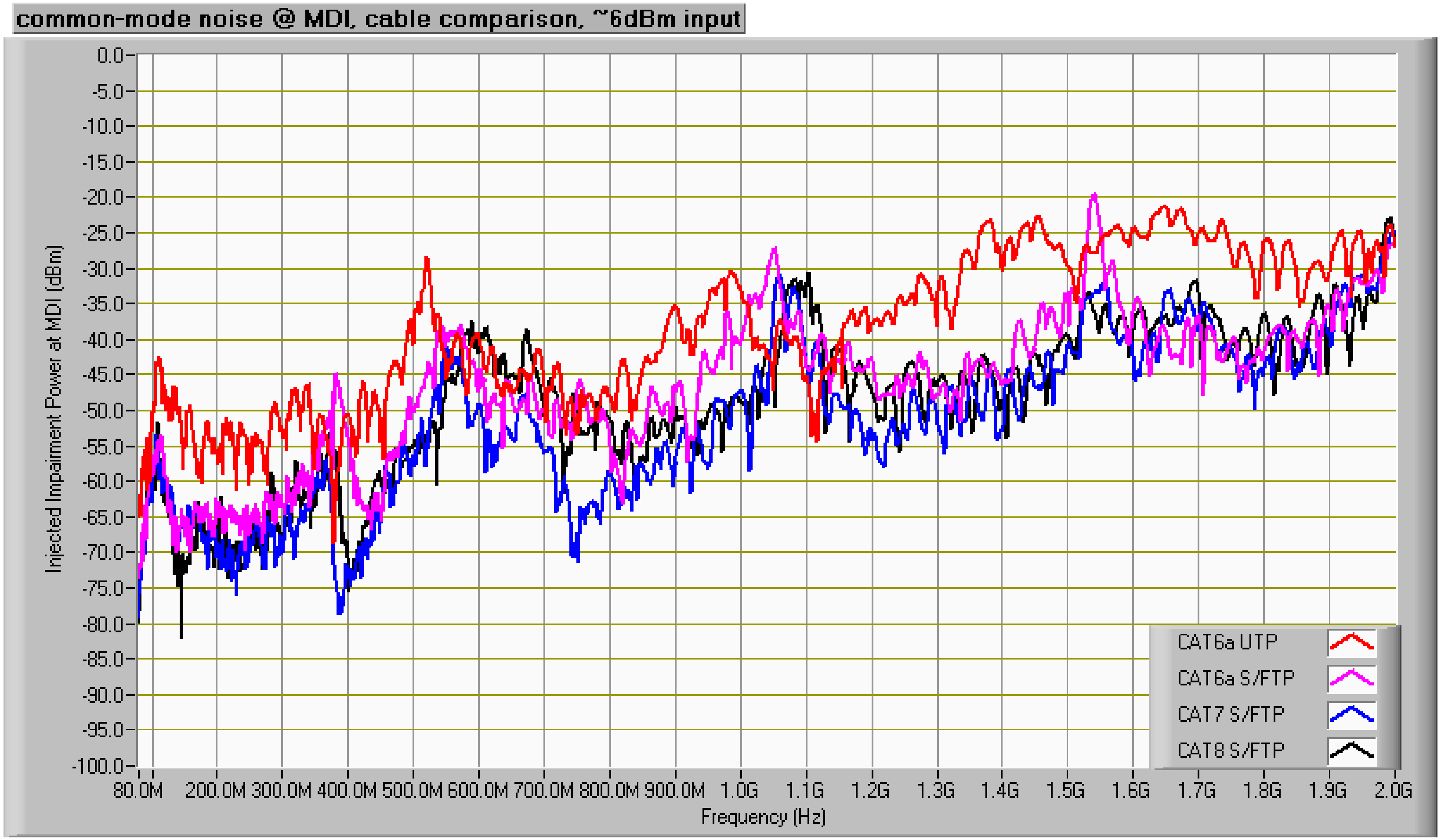
common mode noise @ MDI, CAT7 S/FTP cable, ~6dBm input
Injected Impairment Power at MDI (dBm)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
-75.0
-80.0
-85.0
-90.0
-95.0
-100.0
80.0M
200.0M
300.0M
400.0M
500.0M
600.0M
700.0M
800.0M
900.0M
1.0G
1.1G
1.2G
1.3G
1.4G
1.5G
1.6G
1.7G
1.8G
1.9G
2.0G
Frequency (Hz)
BI_DA
BI_DB
BI_DC
BI_DD
Avg. (FTP)

CAT8 S/FTP

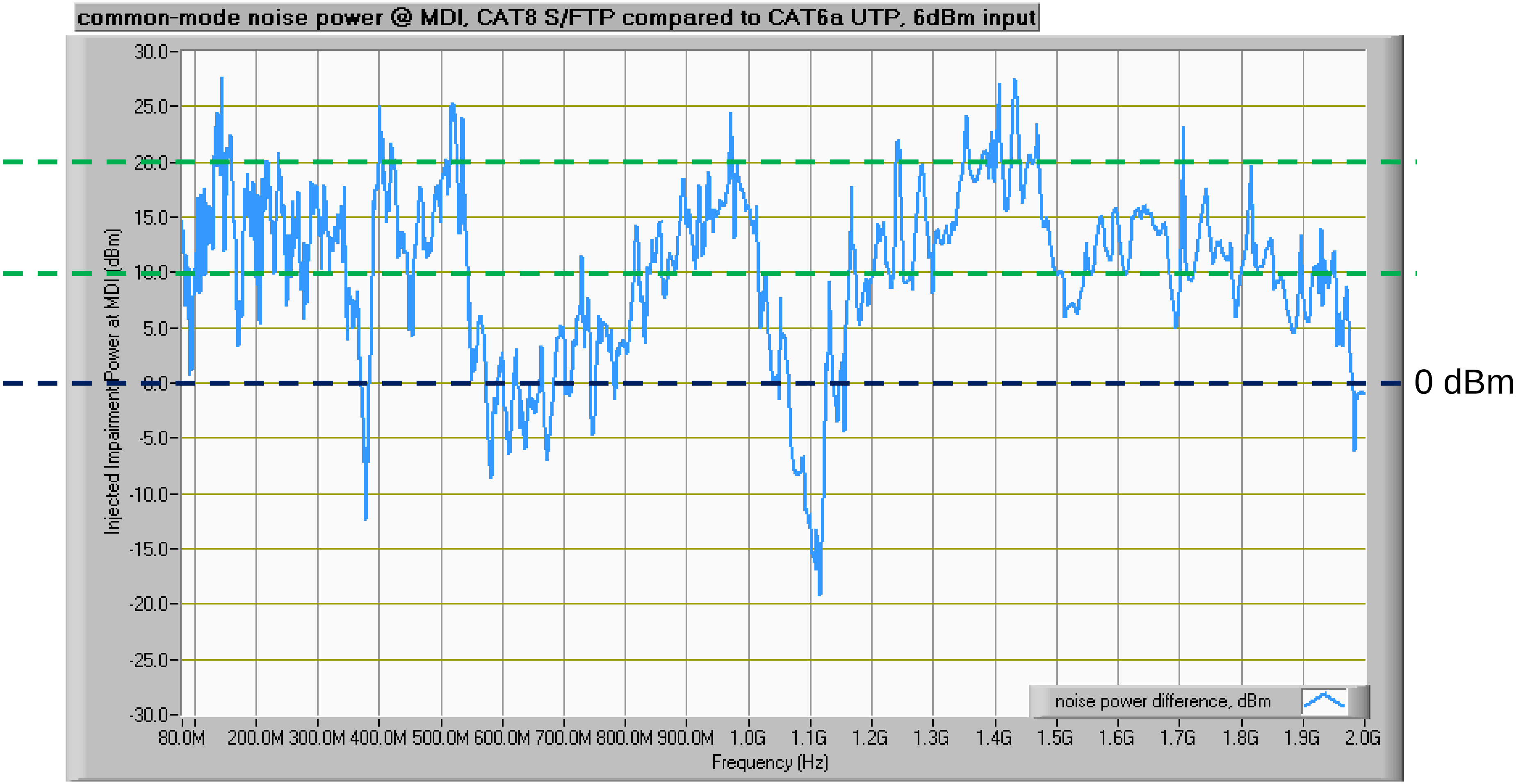


CAT8 S/FTP shows a somewhat higher injected noise than other shielded systems. Note that this prototype channel was not installed in a grounded and bonded patch panel.

Injected Noise at MDI

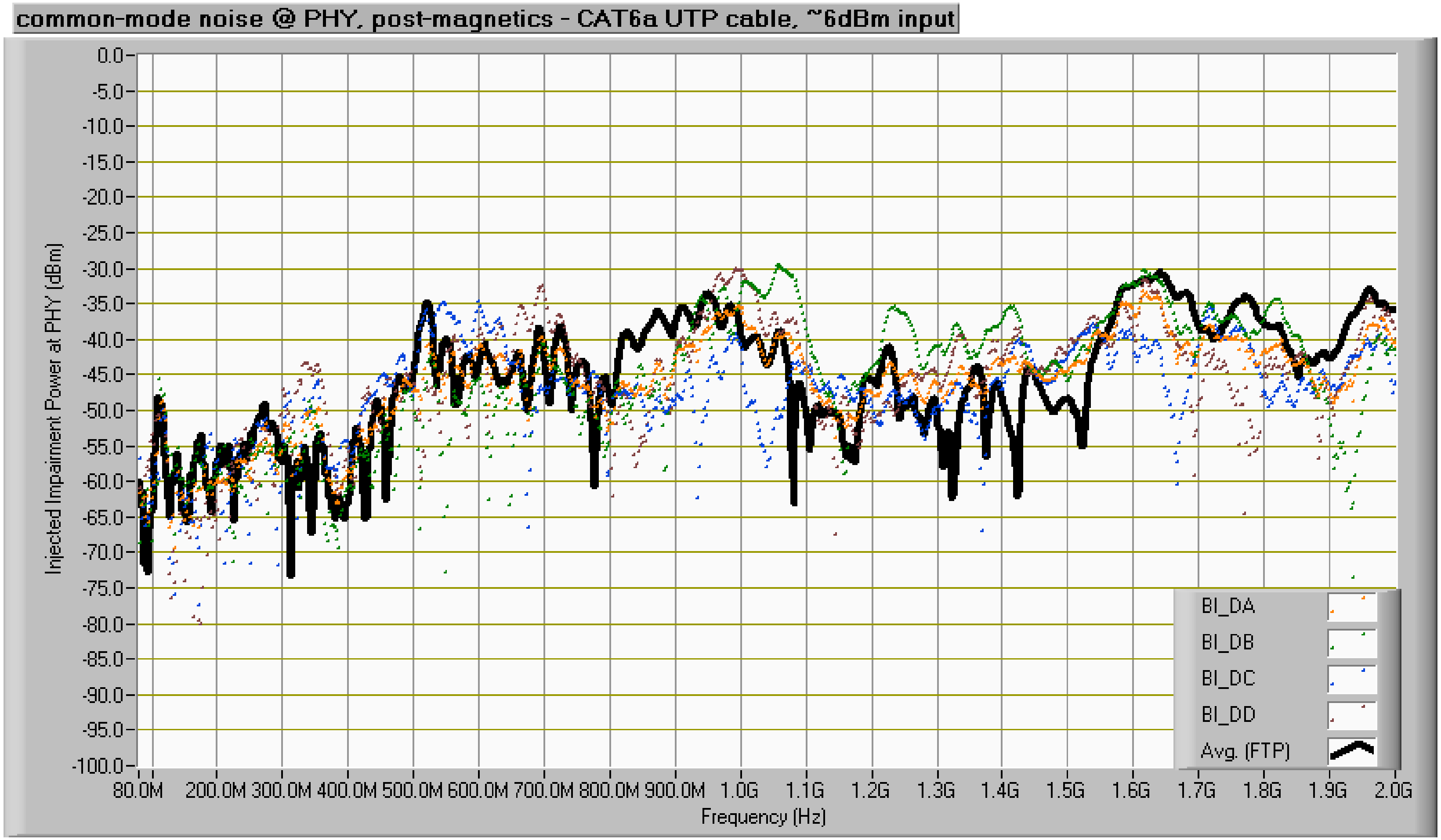


Relative injected noise at MDI
CAT8 S/FTP compared to CAT6a UTP

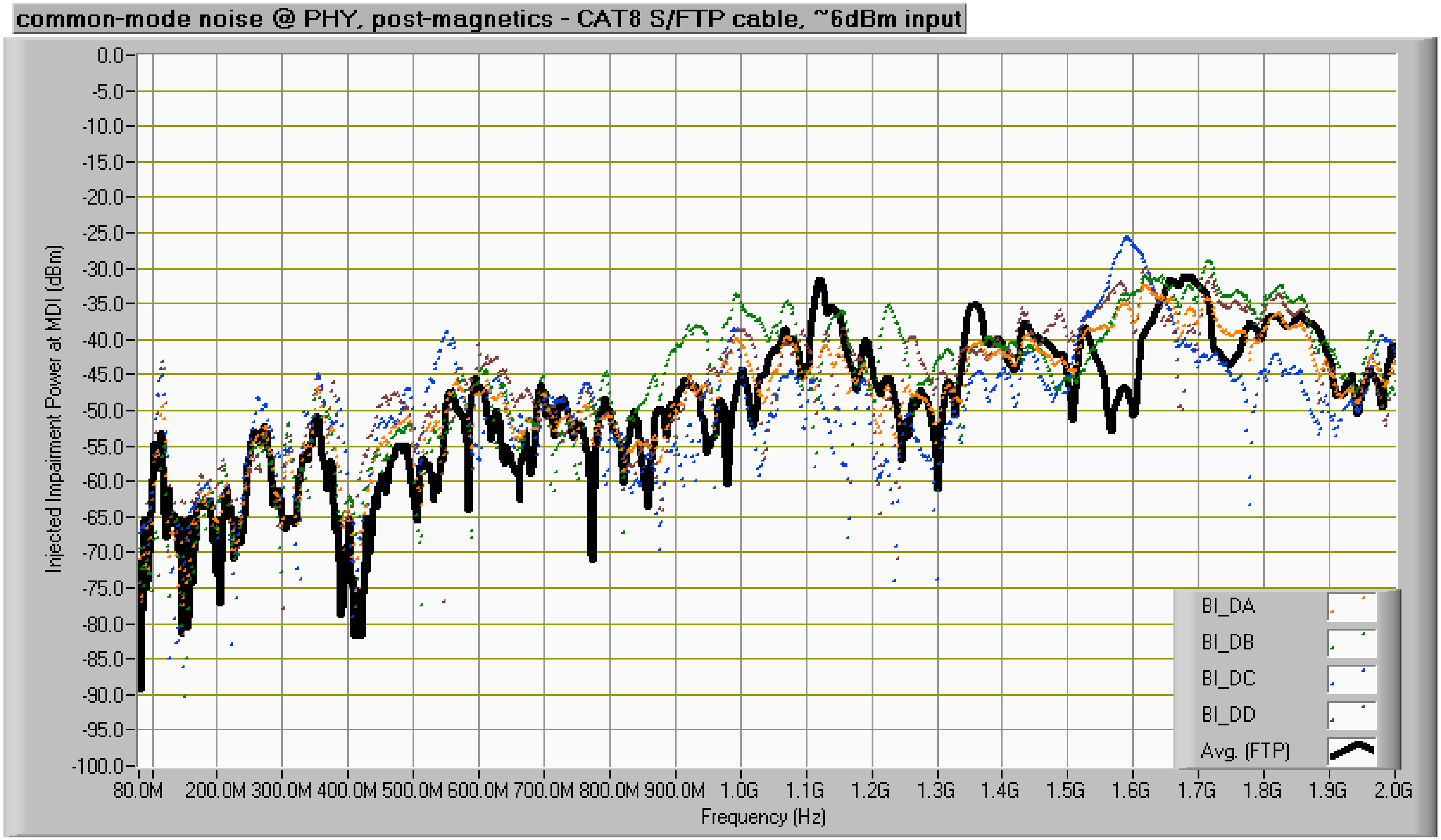


CAT8 noise levels are generally between 1 and 2 orders of magnitude better than CAT6a, even with suspected deficiencies in the CAT8 setup.

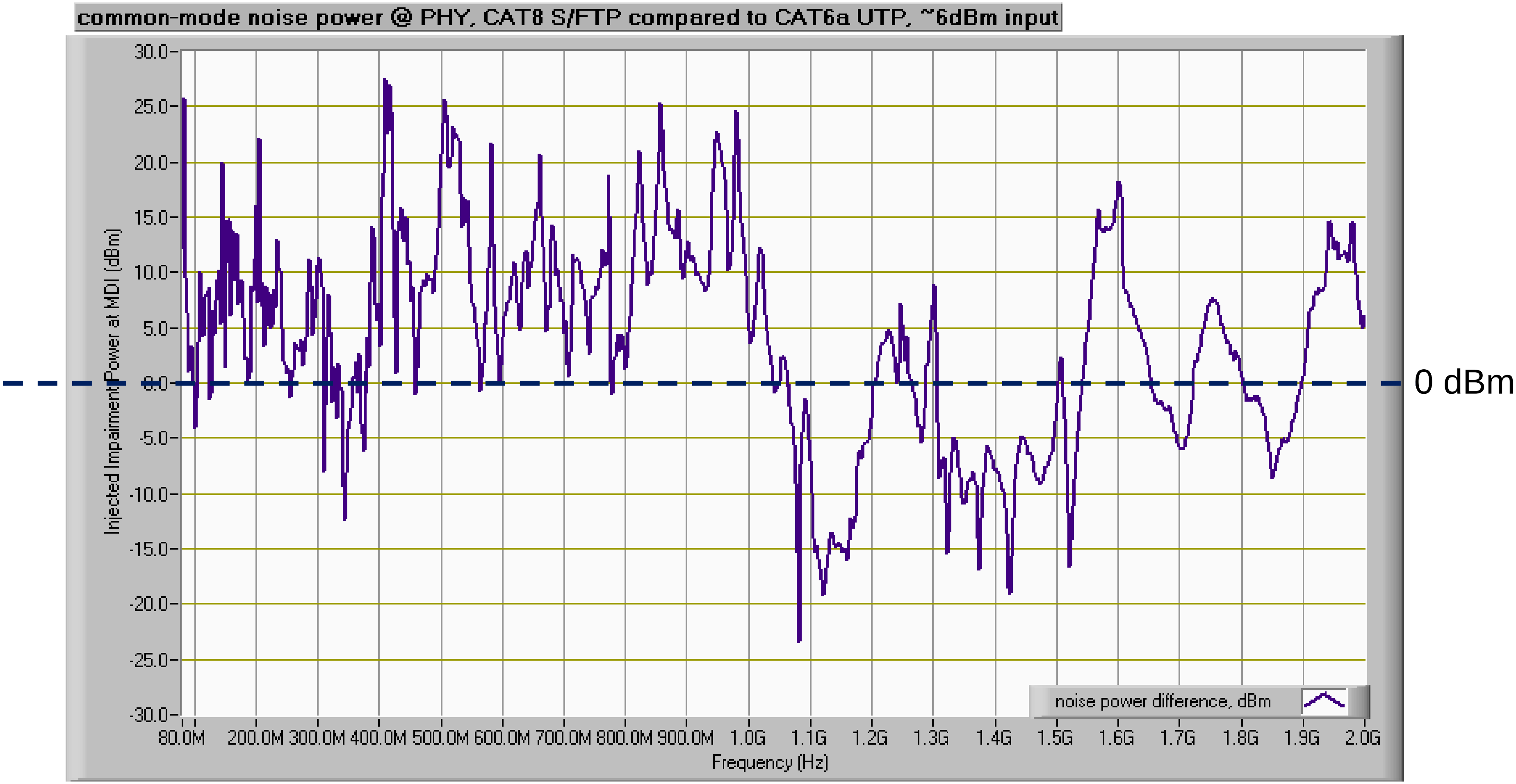
Injected Noise at PHY
CAT6a UTP



Injected Noise at PHY
CAT8 S/FTP



Relative injected Noise at PHY
CAT8 S/FTP compared to CAT6a UTP



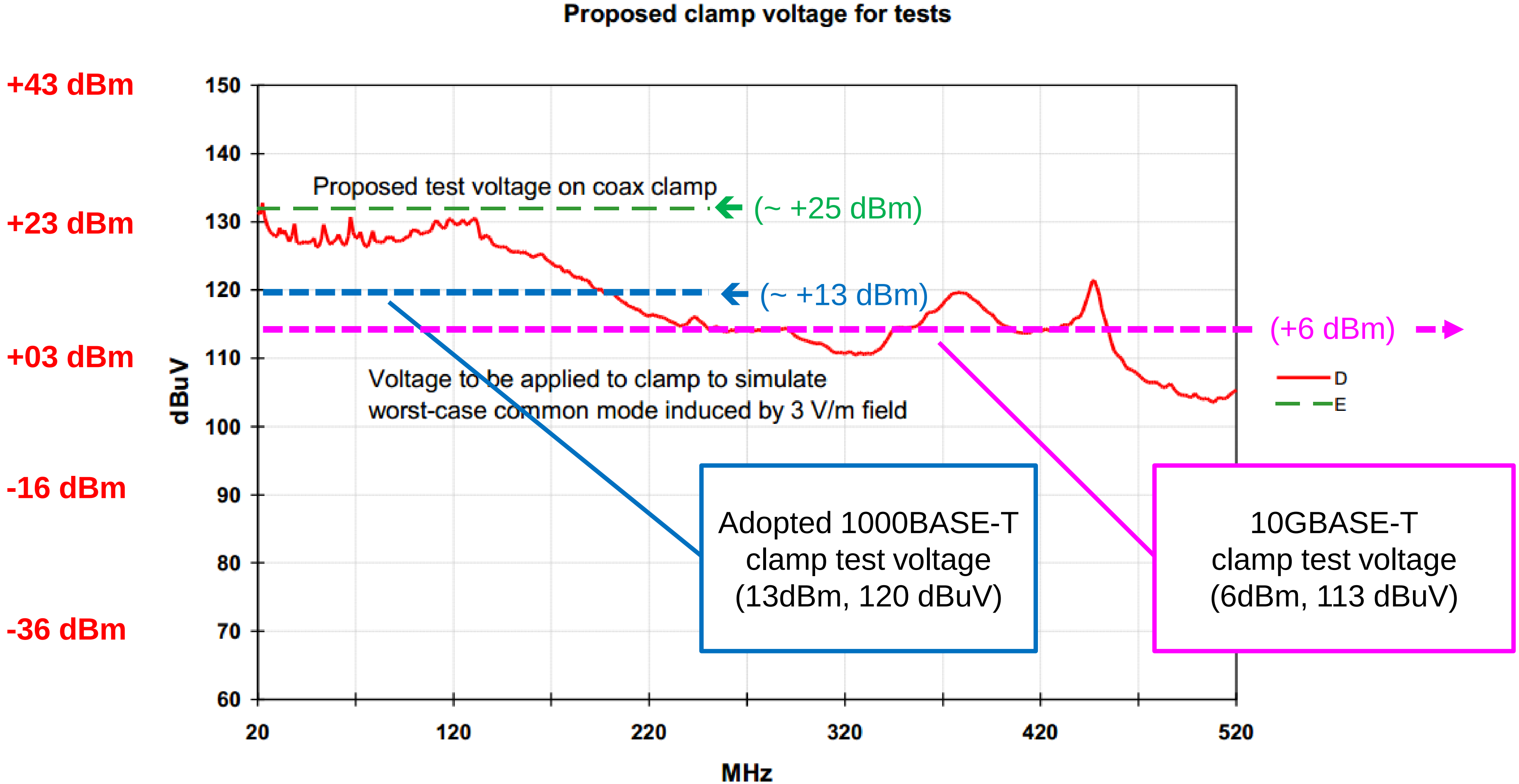
CAT8 S/FTP again shows generally lower injected noise power than CAT6a.
Cause of behavior above >1GHz (UTP better than S/FTP at the PHY) is TBD.

Comparison to other BASE-T Rx CMNR tests

- Two similar test setups have been defined
  - Subclause 40.6.1.3.3
    - Fairly well defined but intended for CAT5e cabling over a 1MHz to 250MHz range
  - Subclause 55.5.4.3
    - Less detail; essentially 40.6.1.3.3 with a different injected power and extended frequency range

- Using 40.6.1.3.3 as a point of reference, let’s see how things stack up

Rx CMNR Source Voltages



Based on "An Improved Common Mode Noise Tolerance Test for 1000BASE-T",
Luc Adriaenssens, IEEEclamp-1998-07-converted.pdf

1000BASE-T Induced Voltage

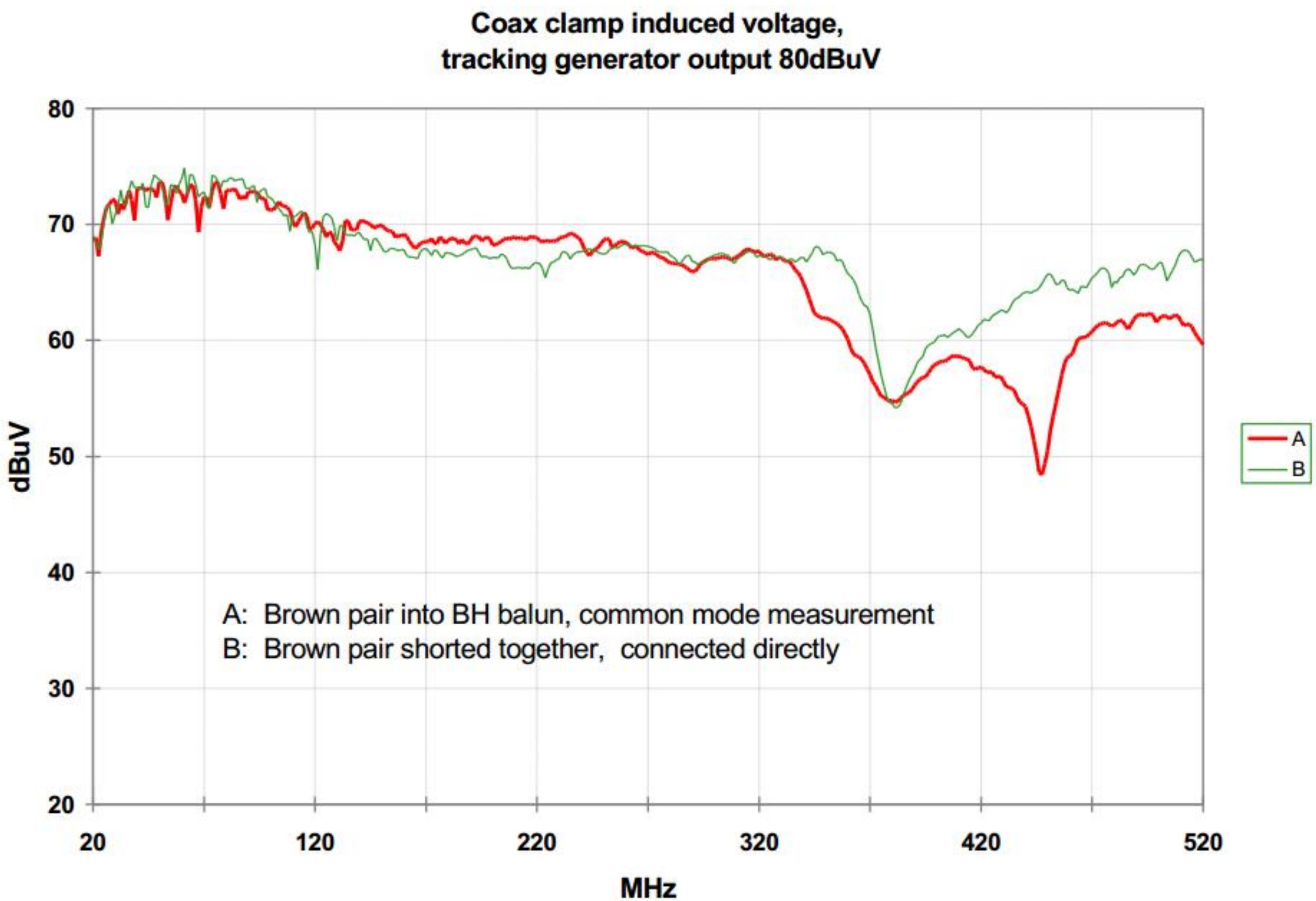
-27 dBm

-37 dBm

-47 dBm

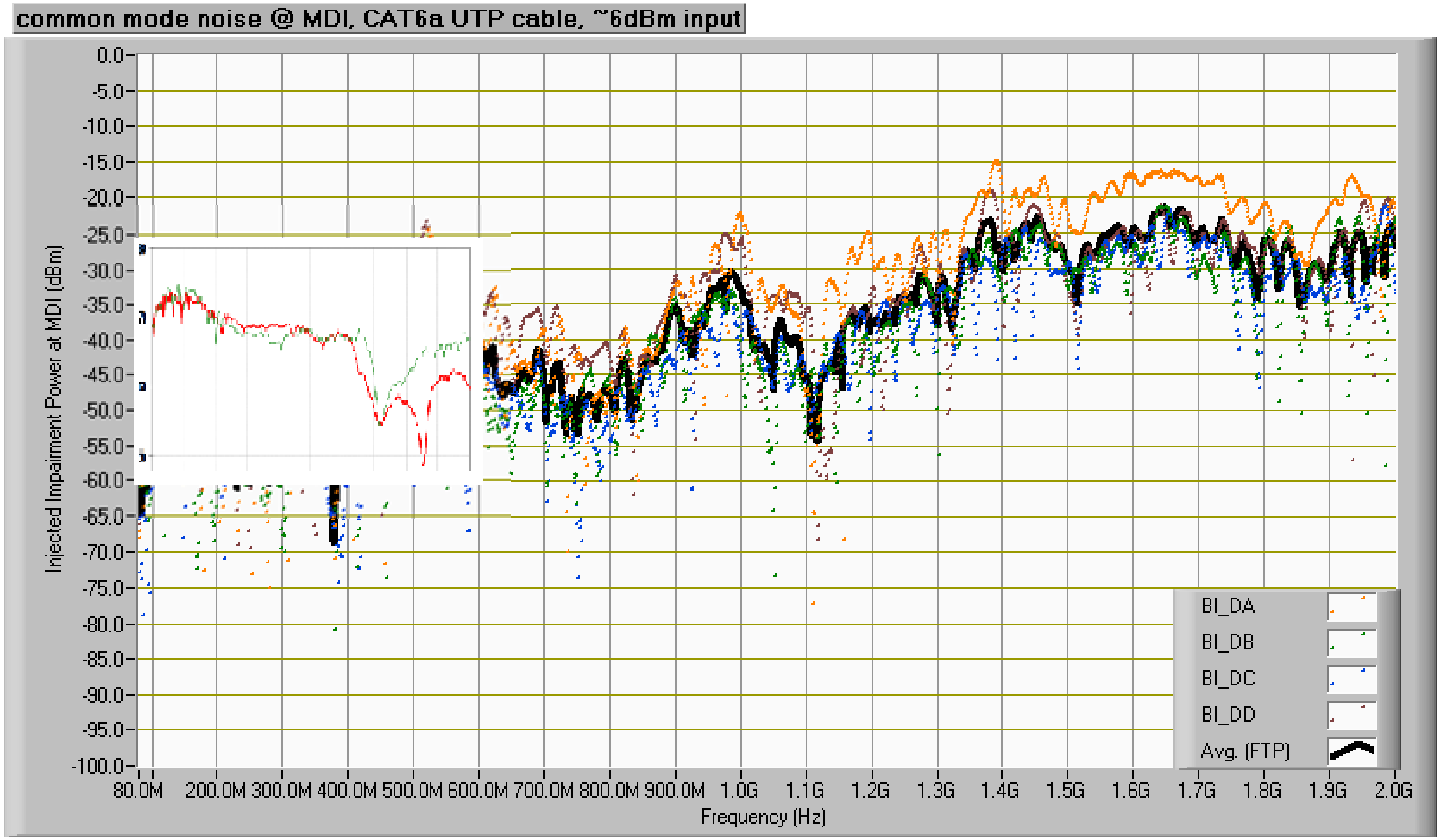
-57 dBm

-67 dBm



Based on “An Improved Common Mode Noise Tolerance Test for 1000BASE-T“, Luc Adriaenssens, IEEEclamp-1998-07-converted.pdf

Induced Voltage Comparison



The 1000BASE-T voltage induced on CAT5e cabling as presented in 1998 are "pixel fit" to the CAT6a UTP data set, showing that presented results are within reason.

Summary & Next Steps

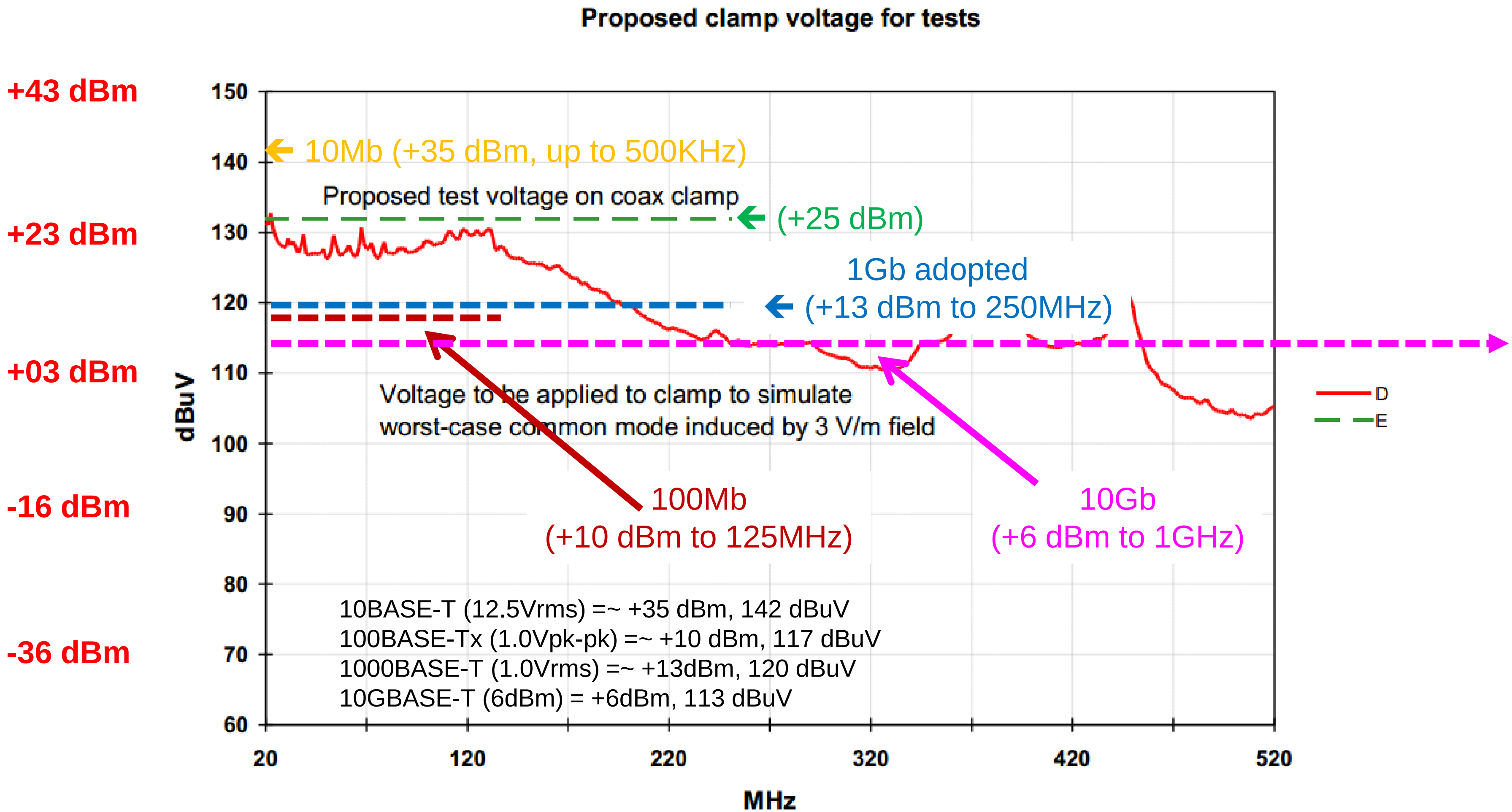
- Measurements of common-mode voltages induced on shielded 30m channels using a modified cable clamp methodology have been presented.
- The results, provided for consideration by PHY implementers and by the Rx CMNR ad hoc, suggest the following:
  - Shielded cabling systems generally demonstrate between one and two orders of magnitude better noise rejection than unshielded systems as measured by noise injected from a coaxial cable clamp.
  - The coaxial clamp test method can, with some modifications, be extended to 2GHz.
- Results will be taken into the Rx CMNR ad hoc for further discussion & investigation.

Thank You!

Questions?

Rx CMNR Source Voltages

10Mb/100Mb/1Gb/10Gb



Are any of these appropriate for 40GBASE-T systems? Further study is required – what noise level represents 3V/m (or 10V/m) fields applied to improved cabling?