Clarifying “Induced Common Mode Voltages on Shielded Twisted Pair Cabling”

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Summary

This contribution is a follow-up to cibula_3bq_02a_1114.pdf offering a few clarifications, some additional analysis of previously presented results, and some ongoing and planned extensions of this work.

Clarifications include:

- Confirming that the focus is on differential mode voltages resulting from induced common-mode noise
- Noting that the measurement setup includes a 100ohm-to-50ohm balun to facilitate connections to single-ended instruments
- Confirming that the noise plots show the differential noise on each pair at the MDI and PHY that results from applying a nominal +6dBm signal at the DUT end of the cable clamp
- Presenting noise results with max/min envelopes
- Providing max and min noise values (both dBm and mV)

Extensions (“new stuff”) includes:

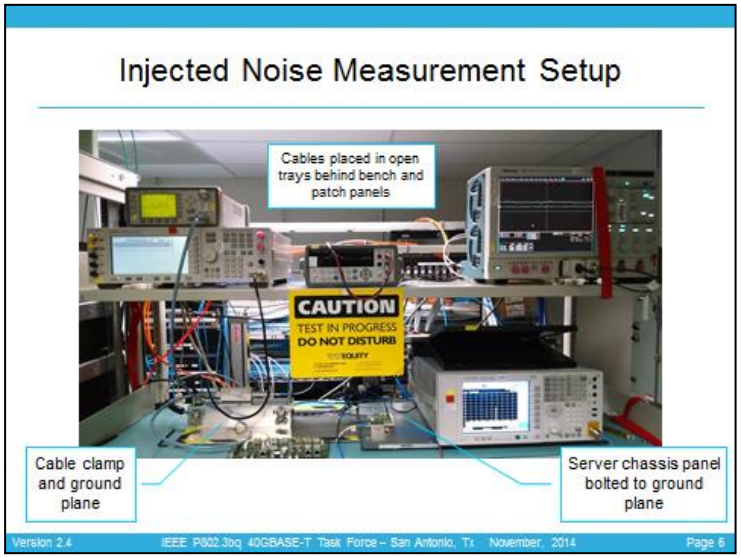
- Measurements of the unloaded cable clamp response
- Review of some elements of the 1000BASE-T cable clamp validation procedure
- Some work in process for future ad hoc meetings

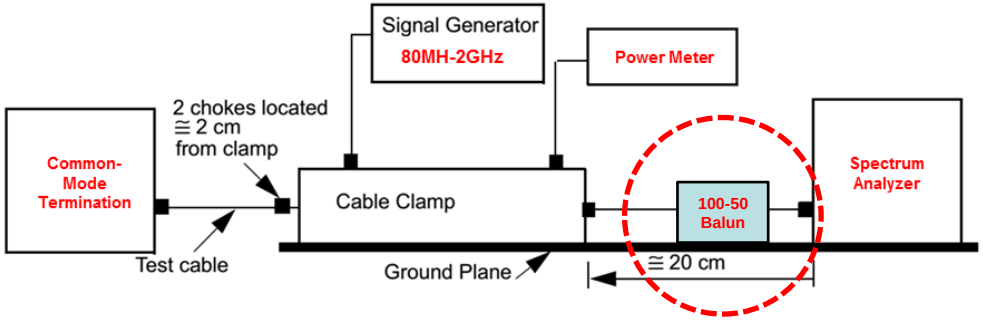
Rx CMNR - What's the goal?

- Characterize the sensitivity of the PMA receiver to common-mode noise from cabling systems that generally result when the cabling & interconnect system is subjected to electromagnetic fields.
  - External electromagnetic fields induce common-mode noise in (primarily) cabling systems.
  - Due to imbalances in cabling, connectors, magnetics, PCB traces, etc., the induced common-mode noise creates a differential-mode noise signal that, in general terms, reduces the PHY SNR operating margin.
- Induced common-mode noise frequencies and powers should be aligned with required systems-level EMC tests
  - Example: The 1000BASE-T cable clamp test is intended to simulate the effects of a 3V/m radiated immunity test using Category 5e/Class D cabling
- Other thoughts?

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
    - Balun case is bolted to the Ground Plane
    - Non-measured pairs are terminated (each wire 50 ohm to GND)
  - 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

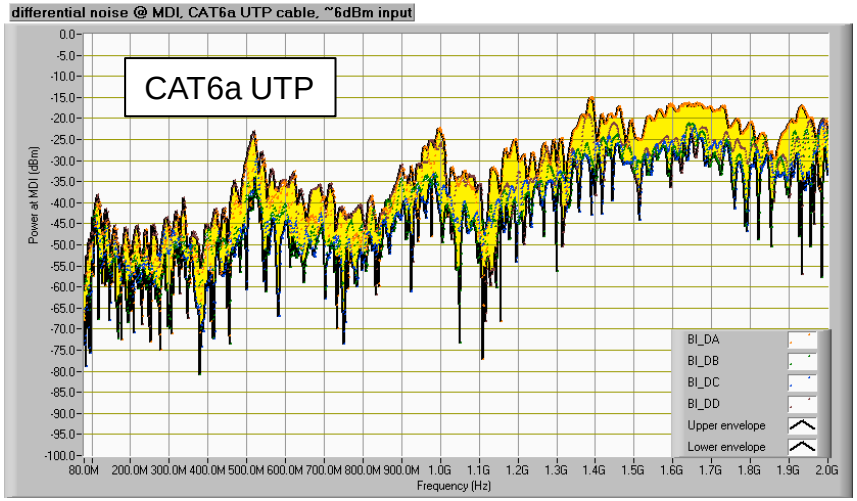
Differential Noise Measurements

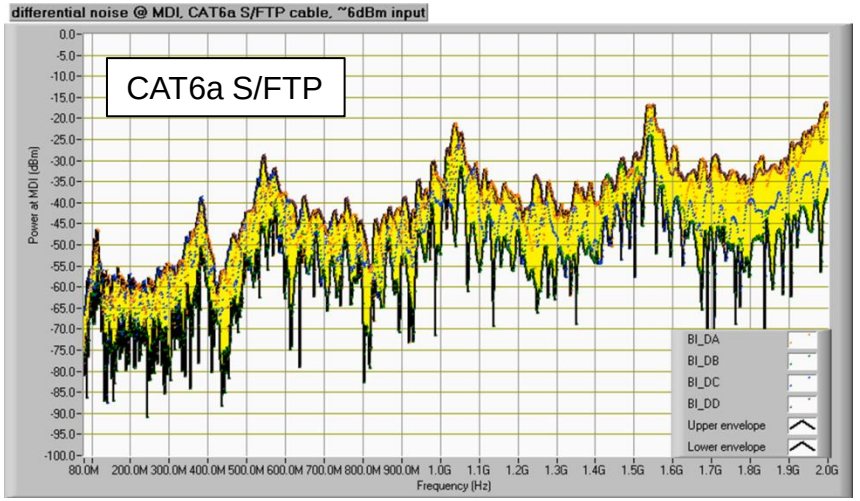
- The following plots show the differential noise measured* at the MDI (4 cable types) and at a 10GBASE-T PHY in a server system (2 cable types)

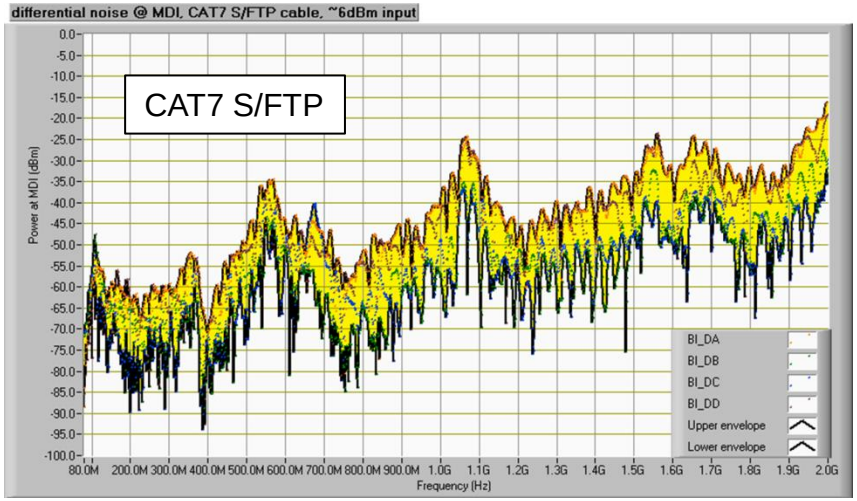
- Results for the 4 cable pairs are presented with max/min envelopes
  - Noise at the MDI for all cable types
  - CAT6a UTP vs. CAT8 S/FTP at MDI
  - CAT6a UTP vs. CAT8 S/FTP at the PHY

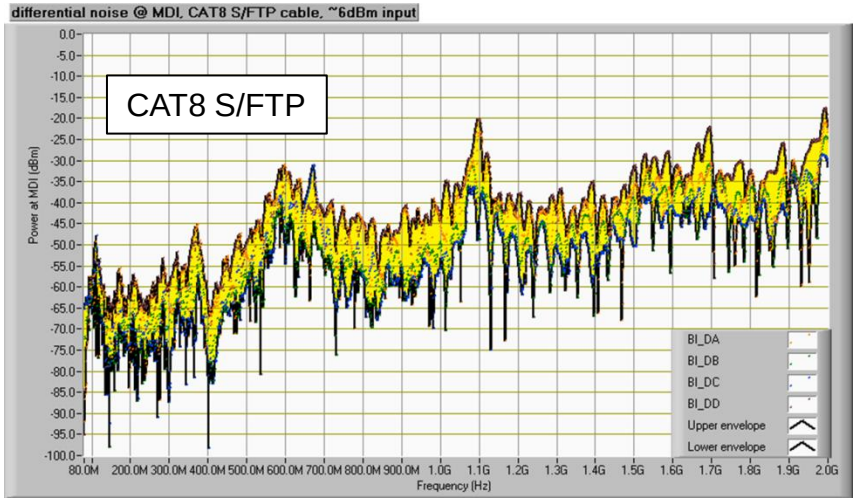
** Using a 100 ohm to 50 ohm balun to perform differential-to-single-ended conversion. Measurements are not corrected for balun insertion loss.*

Differential Noise at MDI
Max/Min envelope representation









"Big" slides are in the backup section

Max/Min differential voltages at MDI (80MHz to 2GHz)

Cable Type	Trace	Full range (80MHz - 2GHz)						
		Max DM noise (dBm)	Max DM noise (mV)	Max DM noise Freq (MHz)	x	Min DM noise (dBm)	Min DM noise (mV)	Min DM noise Freq (MHz)
CAT6a UTP (MDI)	BI_DA	**-15.07**	**39.44**			-77.12	0.0316	
	BI_DB	-21.30	19.26			-80.92	0.0201	
	BI_DC	-21.16	19.57			-79.94	0.0253	
	BI_DD	-19.13	24.71			-69.38	0.0760	
	Max envelope	**-15.07**	**39.44**	**1390.00**		-60.88	0.2020	1650.00
	Min envelope	-23.46	15.01	79.98		-80.92	0.0201	379.32
CAT6a S/FTP (MDI)	BI_DA	-16.31	34.20			-78.32	0.0272	
	BI_DB	-23.99	14.30			-91.07	0.0063	
	BI_DC	-20.05	22.24			-87.67	0.0093	
	BI_DD	-16.68	32.77			-86.46	0.0106	
	Max envelope	-16.31	34.20	1990.00		-66.64	0.1041	1540.00
	Min envelope	-23.99	14.13	79.98		-91.07	0.0063	242.82
CAT7 S/FTP (MDI)	BI_DA	-16.09	35.08			-88.67	0.0082	
	BI_DB	-27.65	9.27			-88.83	0.0081	
	BI_DC	-29.53	7.46			-94.03	0.0045	
	BI_DD	-18.99	25.12			-92.80	0.0051	
	Max envelope	-16.09	35.08	2000.00		-71.07	0.0625	2000.00
	Min envelope	-31.94	5.65	81.10		-94.03	0.0045	386.50
CAT8.x S/FTP (MDI)	BI_DA	-20.94	20.07			-92.07	0.0056	
	BI_DB	-24.37	13.51			-98.03	0.0028	
	BI_DC	-28.65	8.26			**-98.21**	**0.0028**	
	BI_DD	-17.56	29.61			-95.18	0.0039	
	Max envelope	-17.56	29.61	1990.00		-69.72	0.0730	1990.00
	Min envelope	-28.65	8.26	153.02		**-98.21**	**0.0028**	**400.87**

Max/Min differential voltages at MDI (80MHz to 1GHz)

Cable Type	Trace	Limited range for comparison (80MHz - 1GHz)						
		Max DM noise (dBm)	Max DM noise (mV)	Max DM noise Freq (MHz)	x	Min DM noise (dBm)	Min DM noise (mV)	Min DM noise Freq (MHz)
CAT6a UTP (MDI)	BI_DA	-22.23	17.29			-75.10	0.0393	
	BI_DB	-33.00	5.00			-80.92	0.0201	
	BI_DC	-29.49	7.50			-78.94	0.0253	
	BI_DD	-23.01	15.82			-69.38	0.0760	
	Max envelope	**-22.23**	**17.29**	**996.82**		-60.88	0.2020	982.45
	Min envelope	-33.76	4.58	79.98		-80.92	0.0201	379.20
CAT6a S/FTP (MDI)	BI_DA	-32.87	5.08			-78.32	0.0272	
	BI_DB	-39.91	2.26			-91.07	0.0063	
	BI_DC	-32.91	5.06			-87.67	0.0093	
	BI_DD	-28.70	8.21			-86.46	0.0106	
	Max envelope	-28.70	8.21	543.16		-66.64	0.1041	976.66
	Min envelope	-40.06	2.22	79.98		-91.07	0.0063	242.82
CAT7 S/FTP (MDI)	BI_DA	-34.55	4.91			-88.67	0.0082	
	BI_DB	-45.53	1.49			-88.83	0.0081	
	BI_DC	-39.31	2.42			-94.03	0.0045	
	BI_DD	-36.88	3.20			-92.80	0.0051	
	Max envelope	-34.55	4.19	567.16		-71.07	0.0625	549.15
	Min envelope	-43.53	1.49	81.81		-94.03	0.0045	386.50
CAT8.x S/FTP (MDI)	BI_DA	-31.02	6.29			-92.07	0.0056	
	BI_DB	-39.21	2.45			-98.03	0.0028	
	BI_DC	-31.04	6.27			-98.21	0.0028	
	BI_DD	-31.92	5.67			-95.18	0.0039	
	Max envelope	-31.02	6.29	595.90		-69.72	0.0730	589.91
	Min envelope	-39.84	2.28	152.02		**-98.21**	**0.0028**	**400.87**

Quick comparison – chamber & clamp

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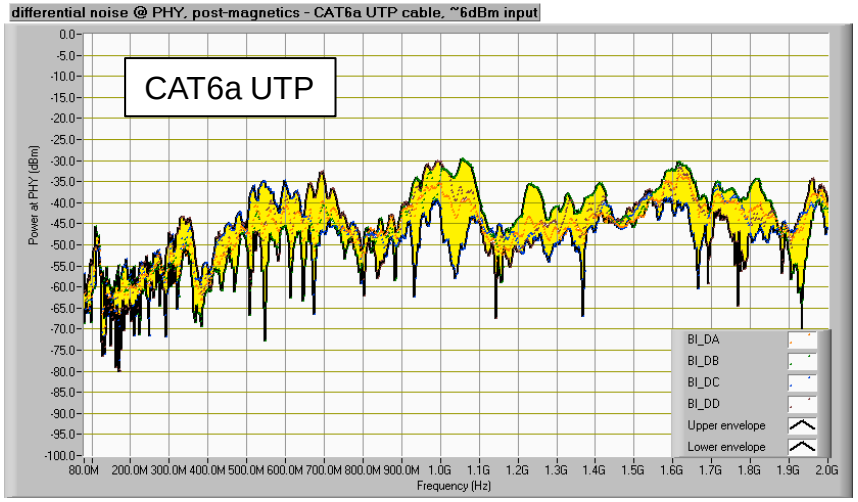
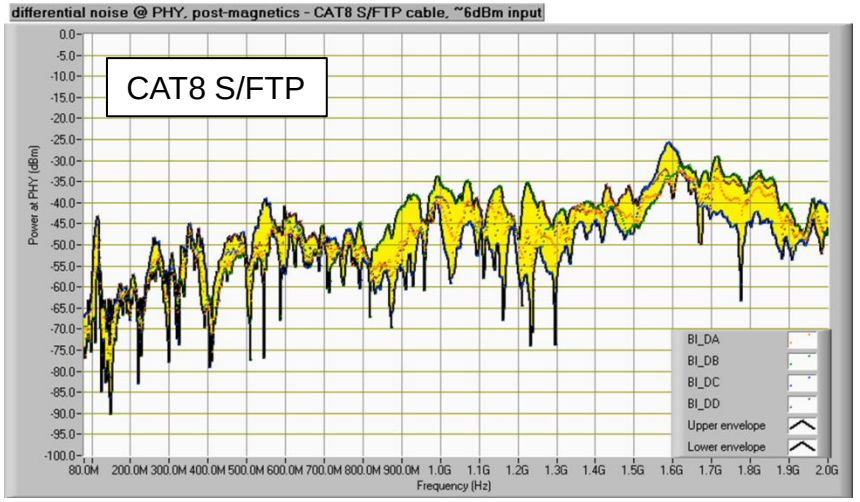
Category	**Description**	**Max DM noise (dBm)**	**Max DM noise (mV)**	**Max DM noise Freq (MHz)**		**Max DM noise (dBm)**	**Max DM noise (mV)**	**Max DM noise Freq (MHz)**
CAT6a	30m Channel F/UTP RJ45	-19.1	25	220MHz		-22.23	17.29	997MHz
CAT7a	30m Channel S/FTP RJ45	-23.5	15	100MHz		-34.55	4.91	567MHz
CAT8.x	30m Channel CAT8 Prototype F/FTP, CAT8 Prototype RJ45	-26.2	11	120MHz		-31.02	6.29	595MHz

- Good news (“glass half full”) observations
  - Both approaches show (generally) improved noise immunity as cable performance improves from CAT6a ⇒ CAT7 ⇒ CAT8
  - Measured noise levels can be said to be “in the ballpark” – not orders of magnitude different
- One obvious opportunity to begin closing the gap
  - Align on differential noise measurement methodologies (oscilloscope vs. spectrum analyzer)

Injected Noise at PHY

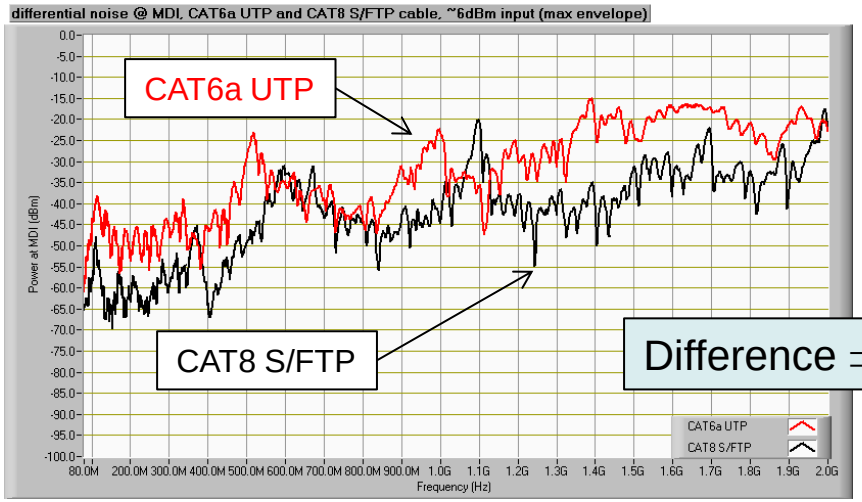




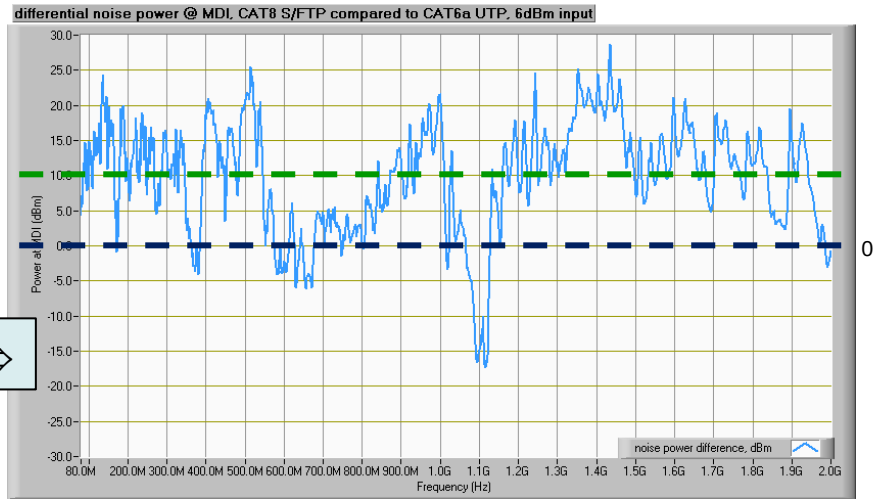
Cable Type	Trace	Full range (80MHz - 2GHz)					
		Max DM noise (dBm)	Max DM noise (mV)	Max DM noise Freq (MHz)	x	Min DM noise (dBm)	Min DM noise (mV)	Min DM noise Freq (MHz)
CAT6a UTP (PHY)	BI_DA	-33.34	4.81			-69.46	0.0753	
	BI_DB	-29.68	7.33			-73.62	0.0466	
	BI_DC	-34.75	4.09			-77.43	0.0301	
	BI_DD	-30.03	7.05			-79.99	0.0224	
	Max envelope	**-29.68**	**7.33**	**1060.00**		-67.44	0.0949	1540.00
	Min envelope	-38.71	2.59	132.58		-79.99	0.0224	170.91
CAT8.x S/FTP (PHY)	BI_DA	-32.44	5.34			-77.45	0.0300	
	BI_DB	-29.11	7.83			-90.21	0.0069	
	BI_DC	-25.79	11.40			-86.17	0.0110	
	BI_DD	-29.95	7.12			-82.61	0.0166	
	Max envelope	**-25.79**	**11.49**	**1590.00**		-73.80	0.0457	1620.00
	Min envelope	-32.44	5.34	147.05		-90.21	0.0069	149.05

Differential noise at MDI & PHY
CAT8 S/FTP compared to CAT6a UTP

@ MDI

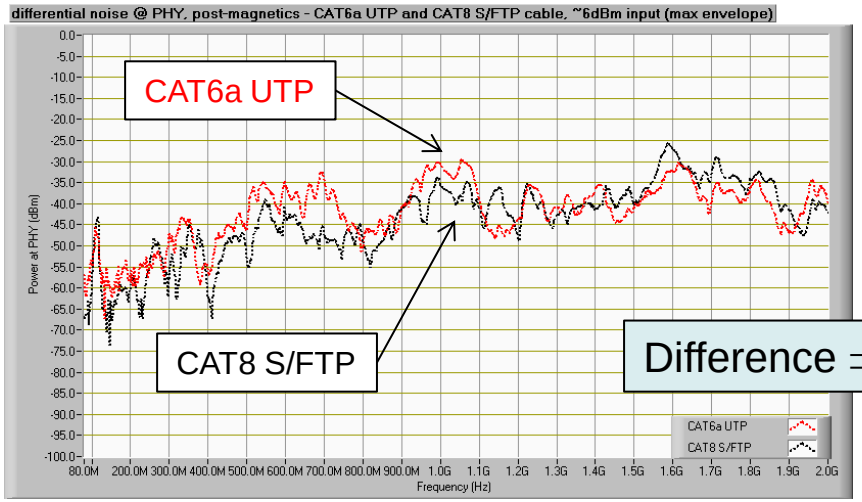


Difference ⇒

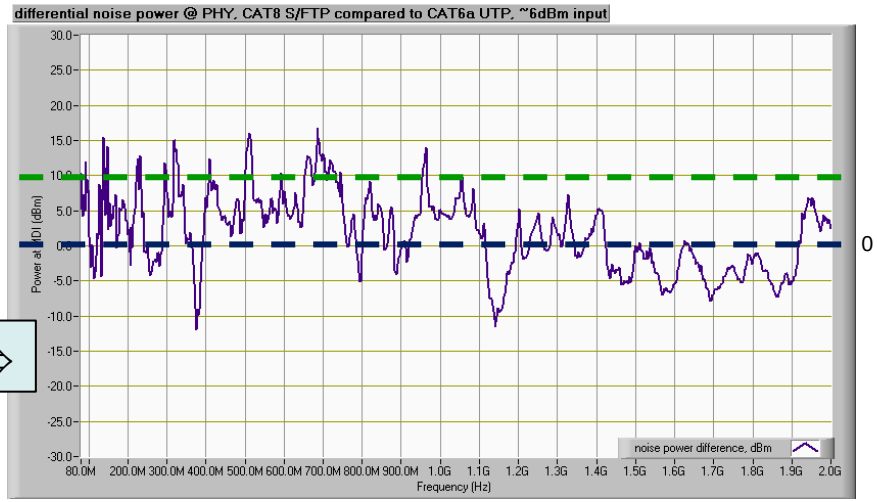


0 dBm

@ PHY



Difference ⇒



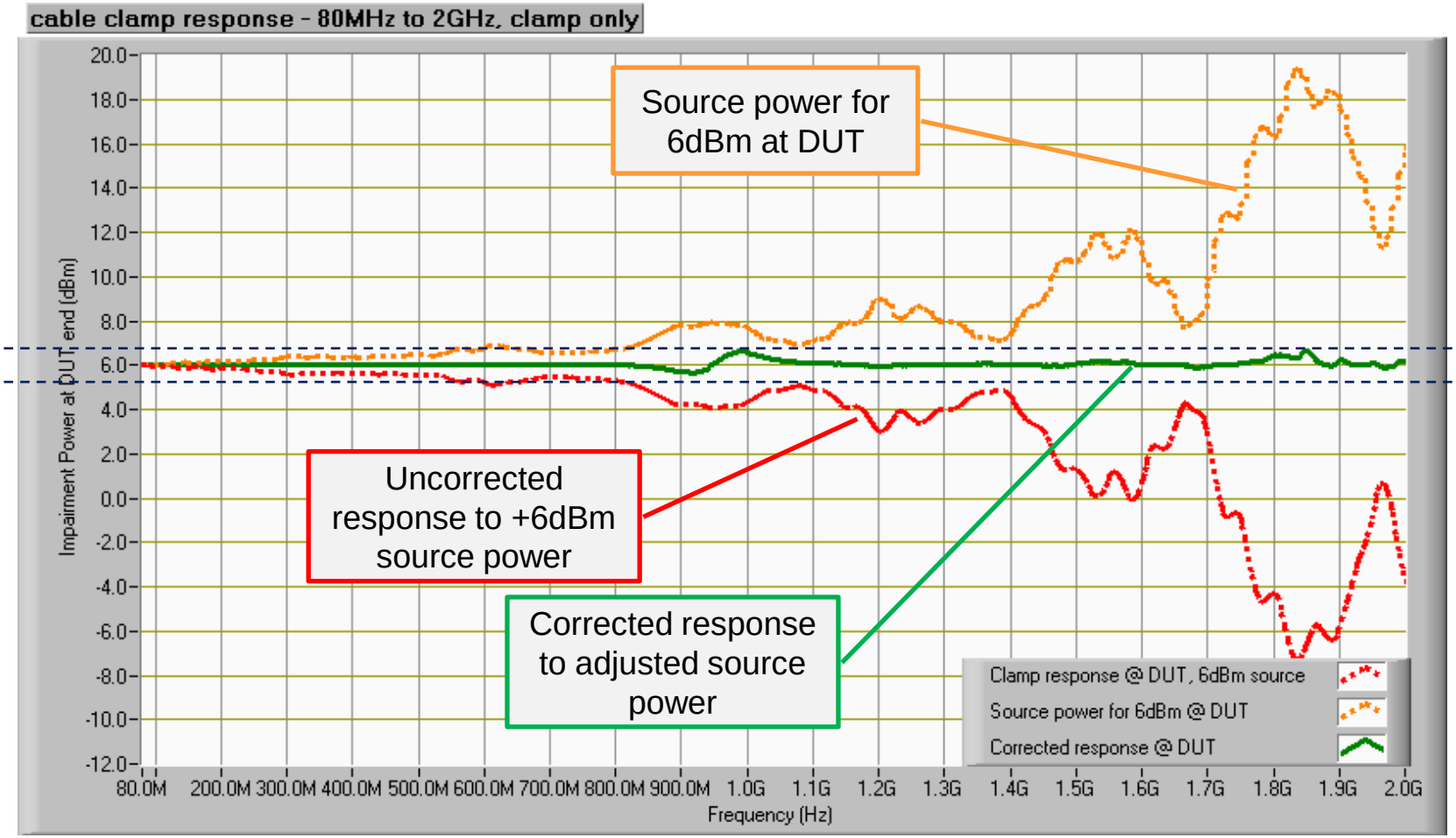
0 dBm

CAT8 noise levels are generally better than CAT6a pre-magnetics; less difference post-magnetics (Mileage can and probably will vary!)

Some Extensions

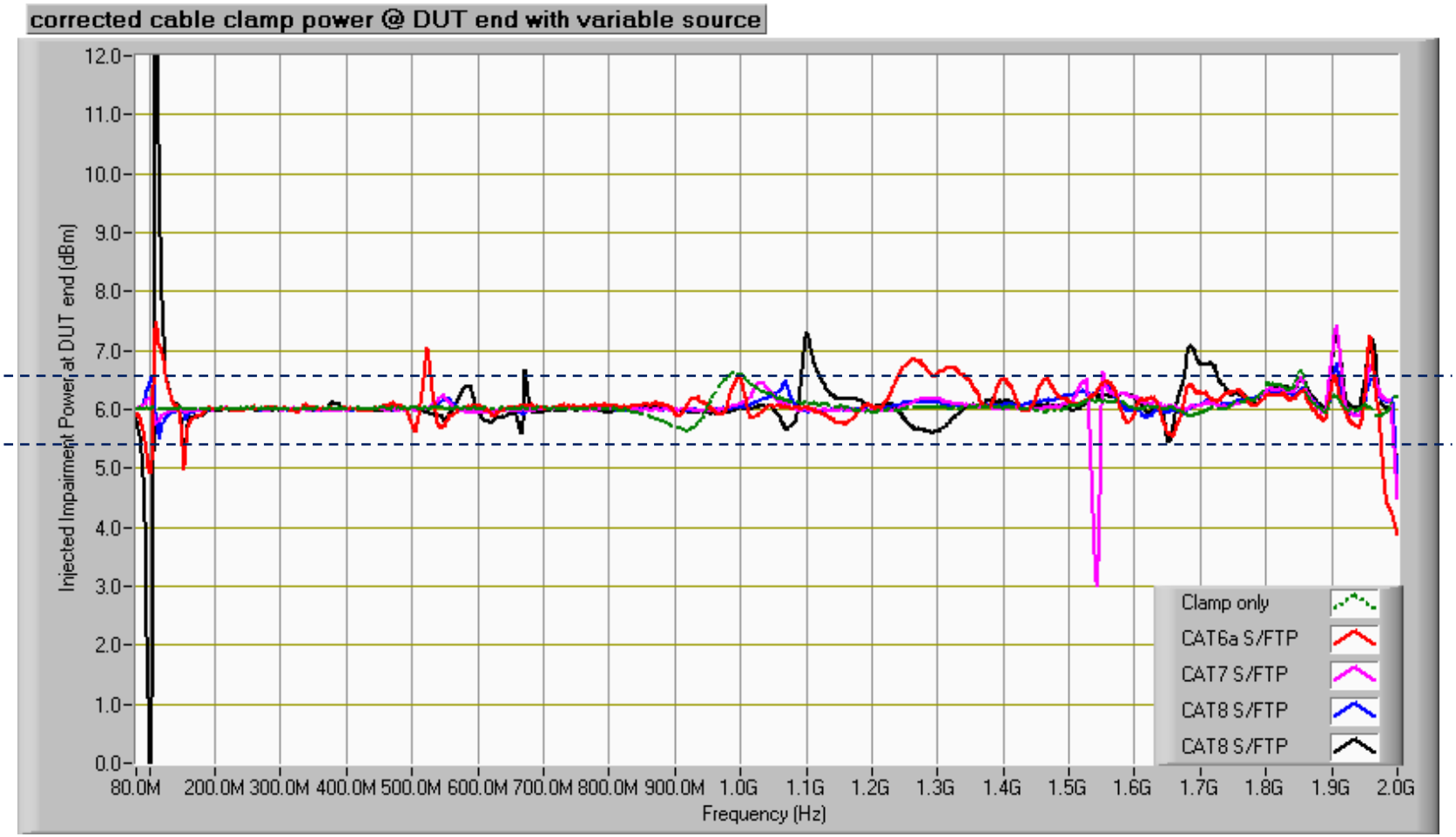
“The New Stuff”

Cable clamp response (Clamp only, no cable)



Unloaded clamp output can be maintained within limits defined in Annex 40B.1, Note 1.
(Note: voltage tolerances have been converted to power in dBm for this plot.)

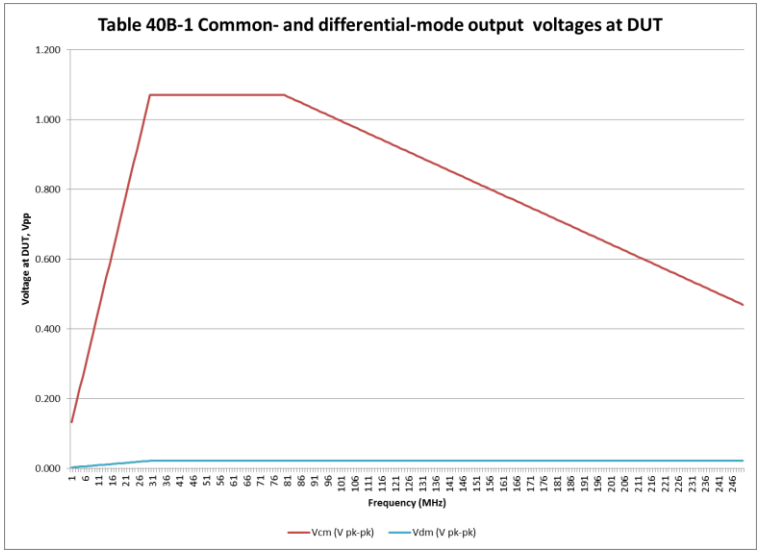
Corrected responses (~6dBm signal) obtained using adjusted source power

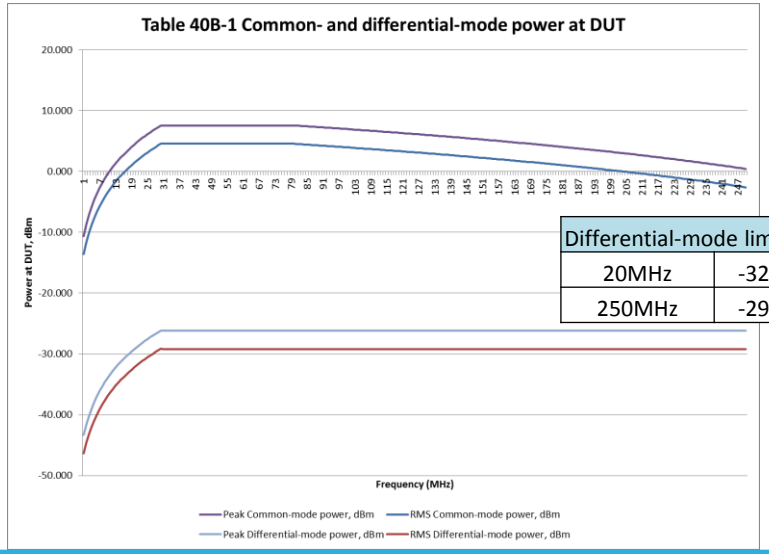


Dashed lines show ±7.5% limits described in Annex 40B.1, Note 1.
(Note: voltage tolerances have been converted to power in dBm for this plot.)

1000BASE-T Rx CMNR Validation

- Defined in Annex 40B.1, Table 40 B-1
- Measures the common-mode and differential-mode noise present at the DUT MDI resulting from the application of a test source signal to the cable clamp input
  - Source signal is a nominal 1 Vrms sinusoid, with source power adjusted so the clamp output voltage (“DUT end”) varies no more than ±7.5% from 20MHz to 250MHz
  - CM and DM noise are measured using a lab balun
- Not (yet) defined for 80MHz to 1GHz (or 2GHz) range!





Differential-mode limit (range)	
20MHz	-32.03 dBm
250MHz	-29.17 dBm

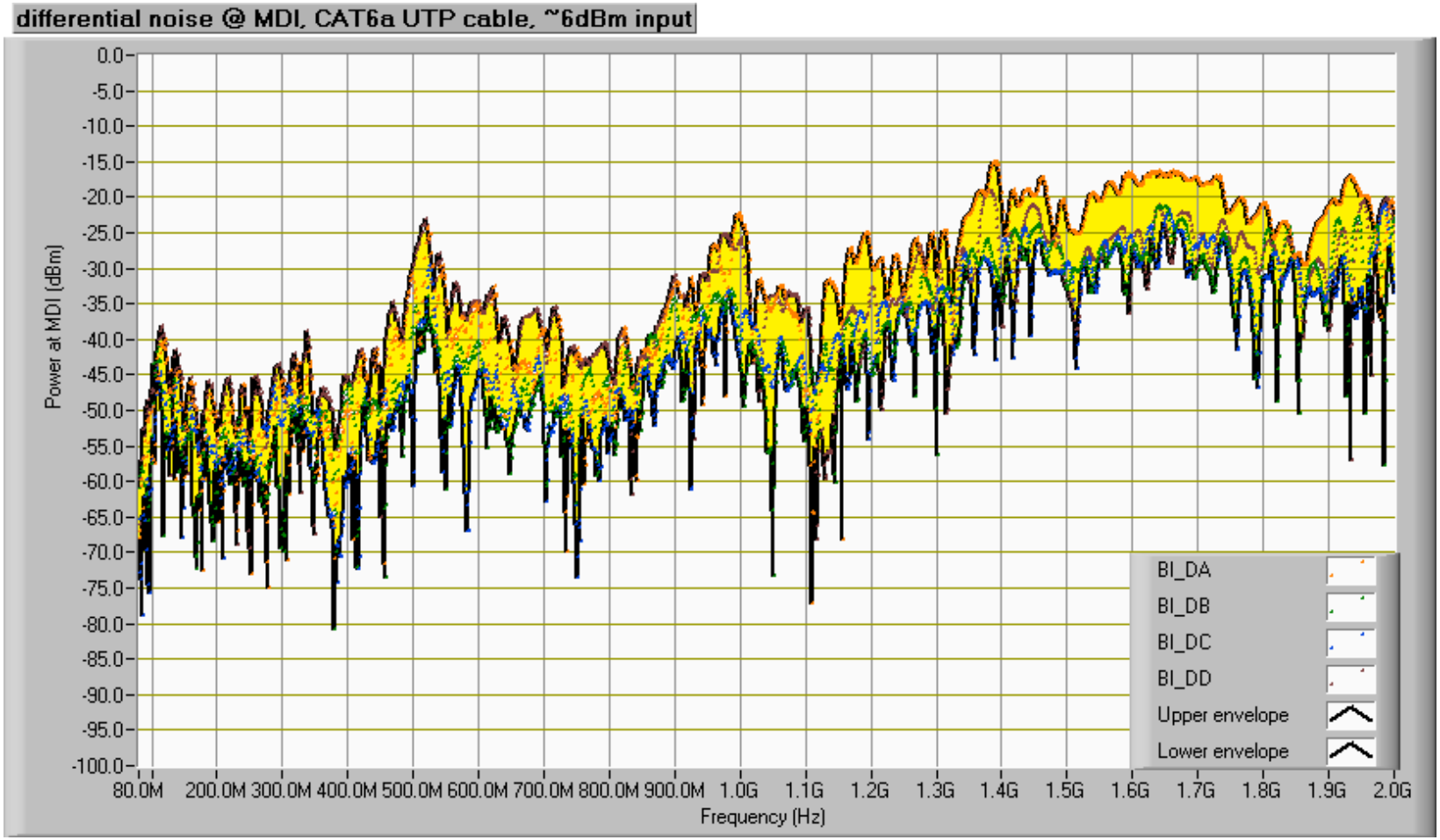
Next Steps

- Operational tests (with cable clamp) to evaluate effects on PHY transceivers
  - Focus on time-to-link, link stability (aka link drops), bit-error-ratio and operating margin
- Chamber measurements
  - Cables
  - Operational tests
- Identify possible improvements for the cable clamp test
  - Correlation/alignment with chamber methods
  - Validation (including harmonizing units – V/Vrms/dBm/dBuV etc.)
  - Other

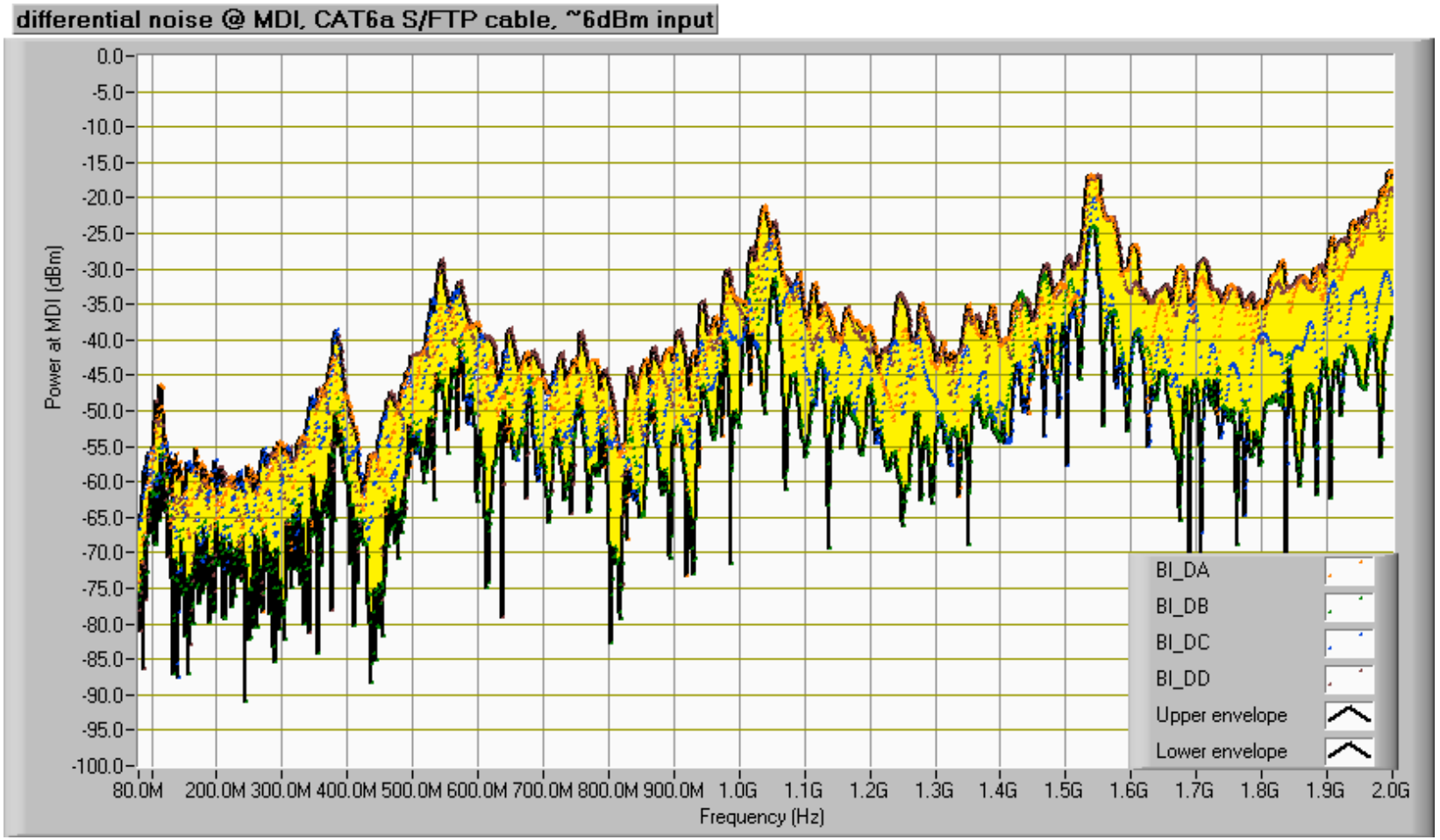
Thank You!

Questions?

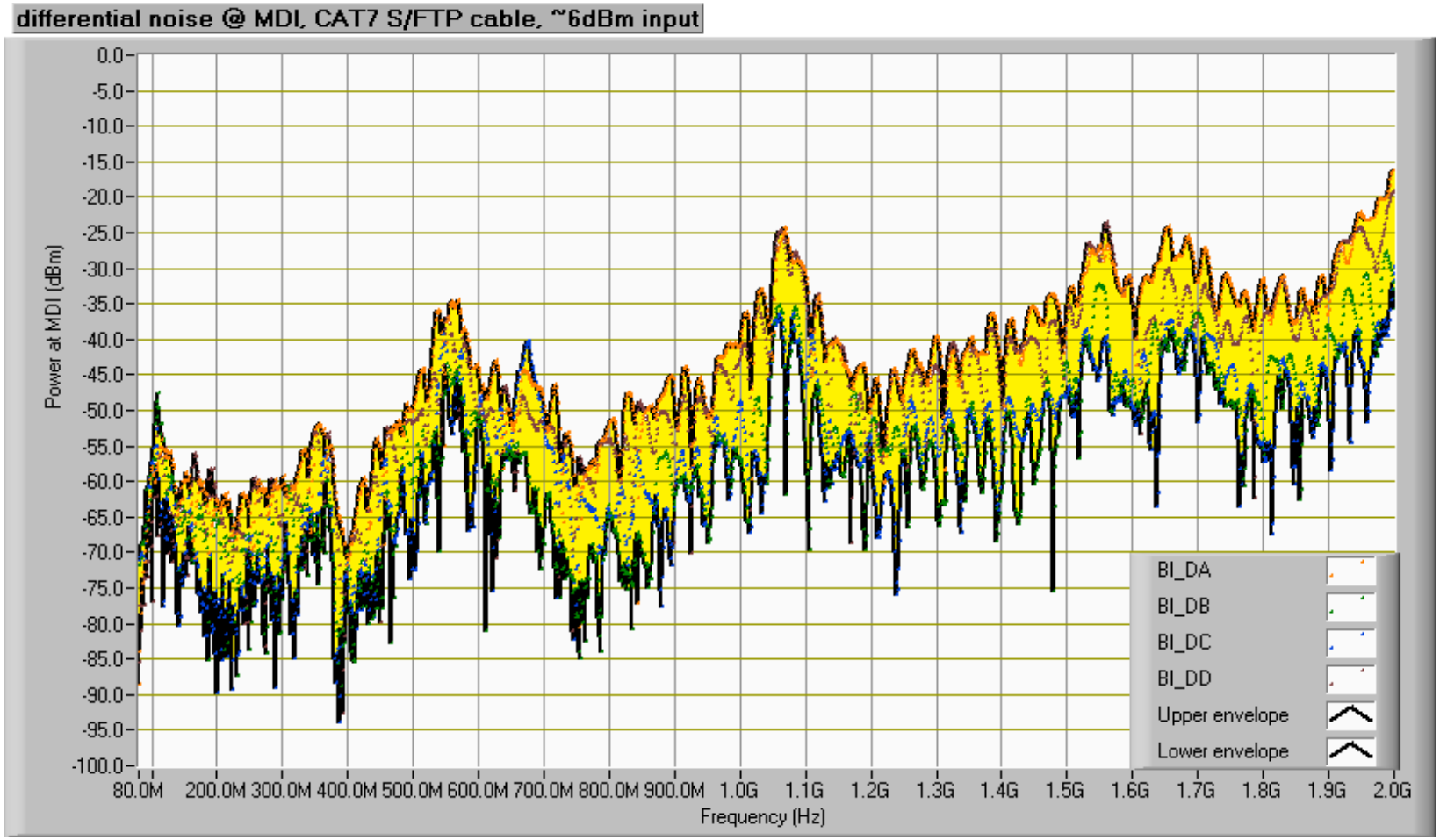
CAT6a UTP (MDI)



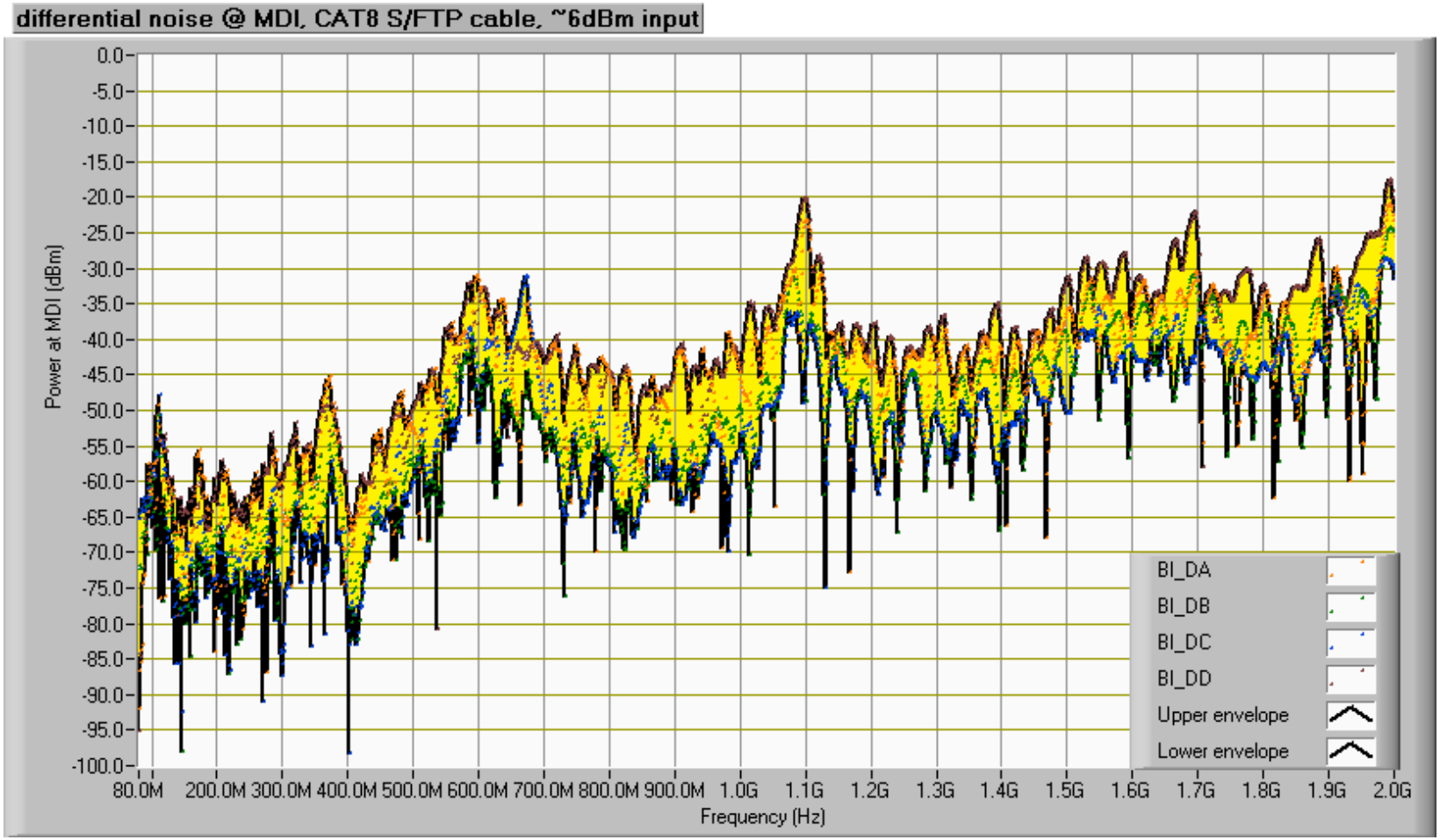
CAT6a S/FTP (MDI)



CAT7 S/FTP (MDI)

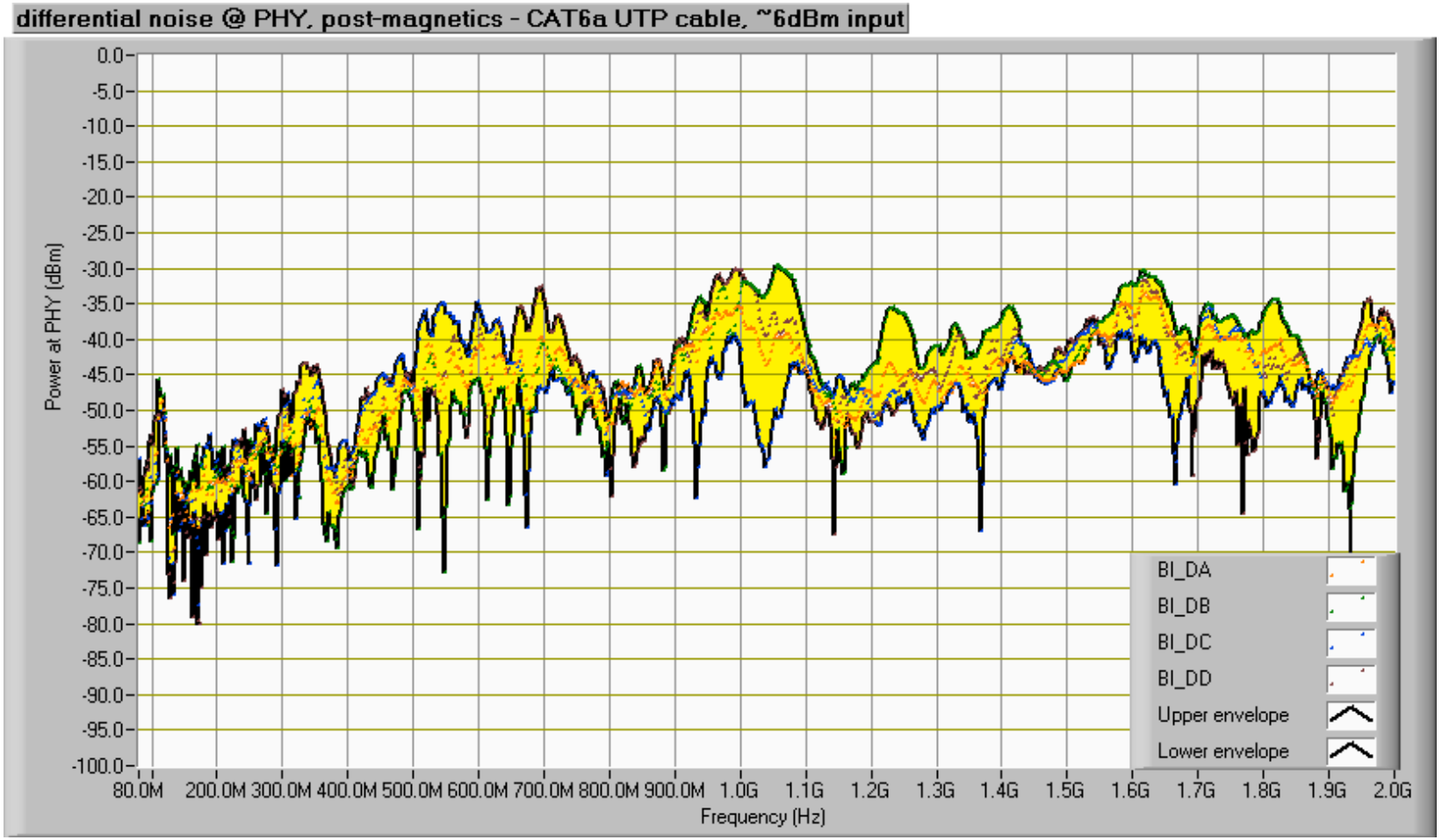


CAT8 S/FTP (MDI)

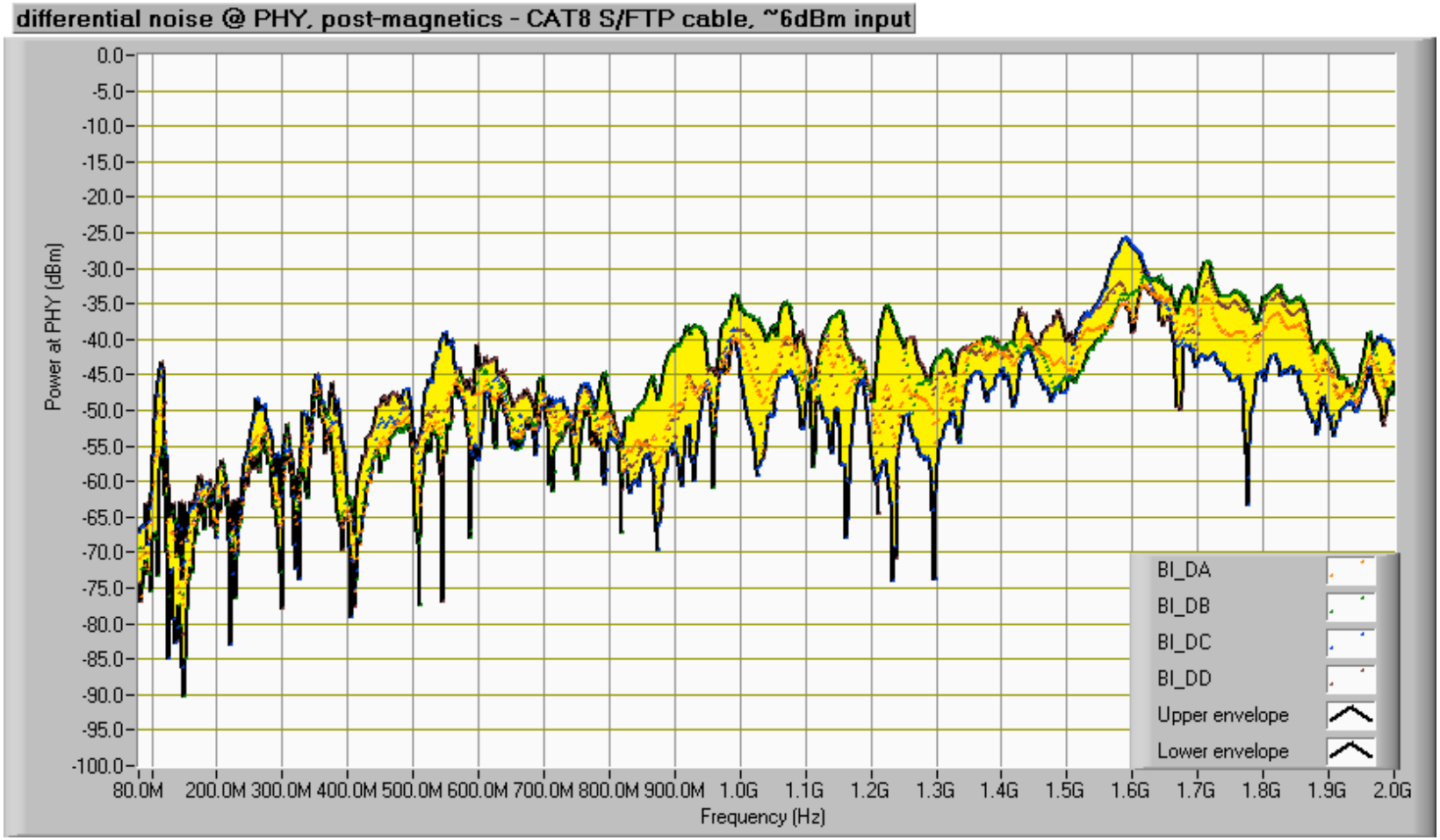


CAT8 S/FTP shows a somewhat higher injected noise than other shielded systems.
Note that this prototype channel was not installed in a grounded and bonded patch panel.

Injected Noise at PHY
CAT6a UTP

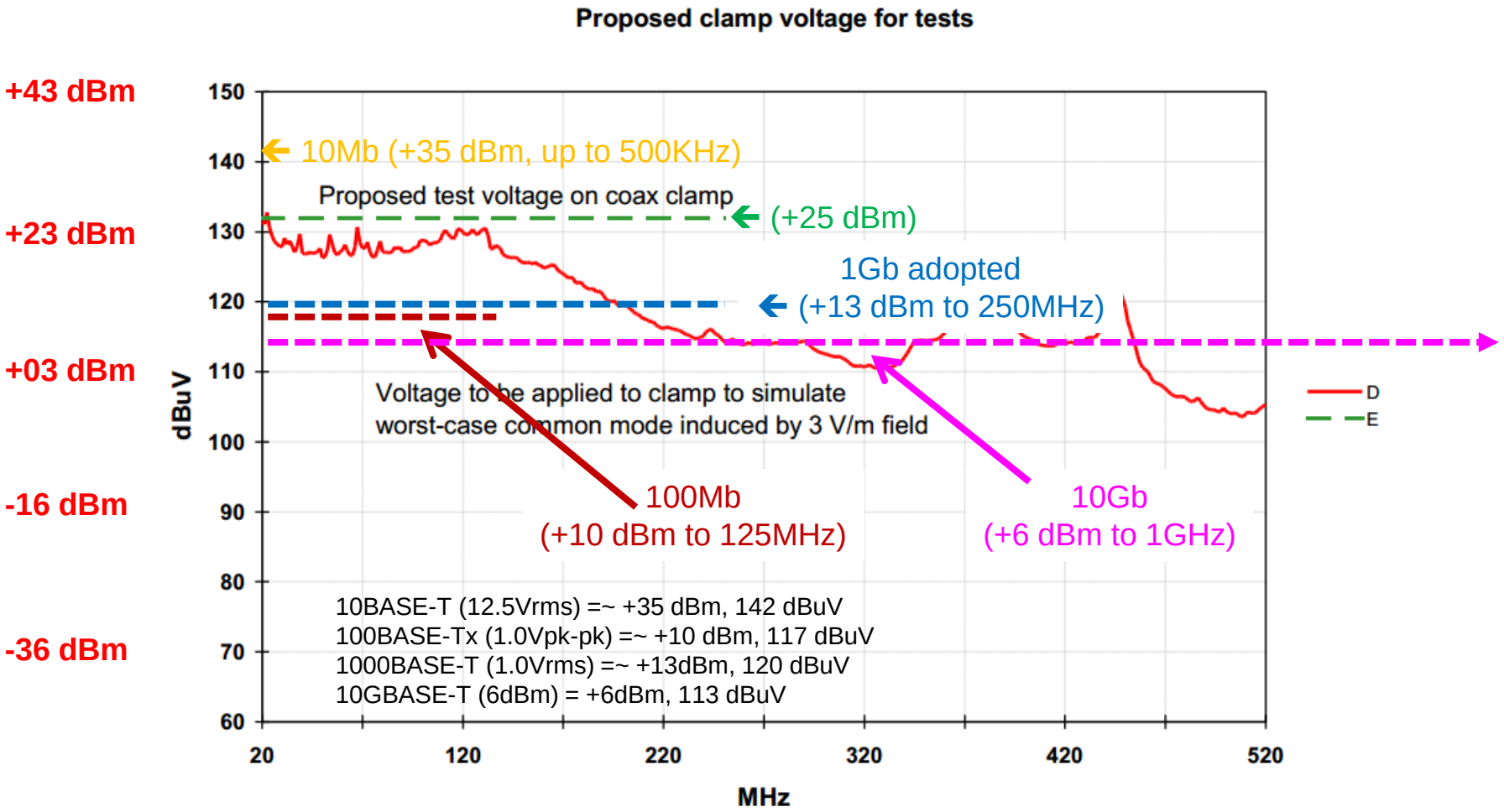


Injected Noise at PHY
CAT8 S/FTP



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?