

A photograph of a surfer in a dark wetsuit riding a large, curling wave. The wave is a deep green color and is breaking over the surfer, creating a tunnel effect. The surfer is positioned in the lower center of the frame, riding the base of the wave. The background is a clear blue sky.

Cable RF Ingress Measurement in an Anechoic Chamber

AQUANTIA®

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Overview

- Purpose: Propose a CMNR common-mode ingress target level based upon measured common-mode and differential RF ingress levels at an MDI port termination on link segment cabling from a controlled external RF field in an anechoic chamber
 - Test data from CKC Labs 3m anechoic chamber (6/3/2008) performed by Teranetics, Inc.
 - Original purpose of this test procedure was to measure RF ingress level differences between UTP and ScTP/STP from different vendors' cable samples
 - Use data from UTP sample to derive a proposed CMNR target level for 2.5G/5GBase-T
- Background for performing test
- Description of measurement procedure and test cases
- Summary of plots
 - Vendor A Cat 6A UTP common-mode and differential mode ingress
 - Vendor B Cat 6 ScTP common-mode and differential mode ingress
 - Vendor C Cat 6 ScTP common-mode and differential mode ingress
 - Vendor D Cat 6 STP common-mode and differential mode ingress
 - Differential-to-common-mode coupling ratio for Vendor A Cat6A UTP
 - Proposed CMNR calibration target levels for 2.5G/5GBase-T
- **For CMNR test purposes, an important result of this contribution is that the common-mode ingress level should roll off with increasing frequency and should not remain constant above 250 MHz as currently defined in Table 113A-2**

Background for Performing Test

- Background issues
 - We were using ScTP and STP cable for active data links inside the test chamber during radiated immunity testing of 10GBase-T products to suppress RF ingress from the test channel and isolate the external field effects to the equipment under test
 - We observed some ScTP patch cords allowed RF ingress levels comparable to UTP patch cords into the test channel
- Purpose of the test procedure
 - Measure RF ingress level differences in ScTP (shield around all four pairs only), STP (per pair shielded), and UTP (Cat 6A) cable samples
 - Use a known calibrated external field strength (10 V/meter) near the MDI port interface so that the measurement data can be used for in-house engineering purposes (important data for CMNR test)
- Test setup
 - Very simple linear cable layout; did not use Bech rack or any complex layout geometry
 - E-field is locally monitored (and calibrated) near the MDI termination test fixture RJ45 port
 - Measure both common-mode and differential mode RF ingress levels for all cable samples; termination test fixture contains no magnetic components, only RJ45 connector
 - Measured RF ingress from 100 MHz to 1000 MHz; could not test down to 80 MHz because of a power amplifier output overload (saturation) problem
- **For CMNR testing, our main interest is the RF ingress measurement data from the Cat 6A UTP sample**

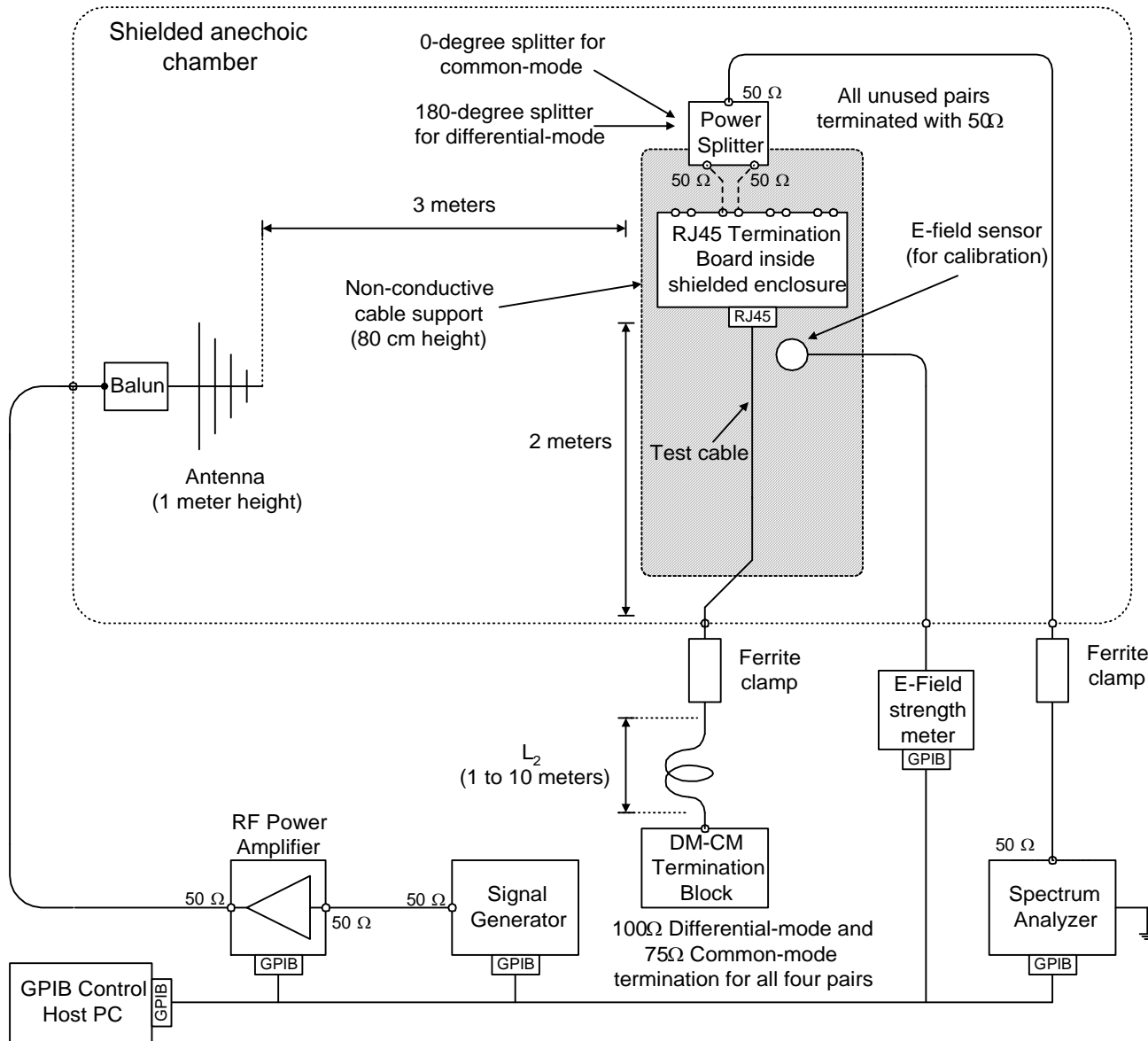
Cabling RF Ingress Measurement Procedure

- Build test setup in chamber as shown in diagram; start with 180-degree splitter on Pair A (Pins 1-2)
- Adjust output level of signal generator and amplifier so that measured E-field level is 10 V/meter; test signal is unmodulated CW (i.e. no 80% modulation at 1 kHz as used in the radiated immunity test)
- Measure and record ingress signal level with the spectrum analyzer at each frequency point (lower limit was 100 MHz due to power amplifier distortion problem)
- Using GPIB control, step signal generator at from 100 MHz to 1000 MHz at 10 MHz intervals and repeat previous three steps at each signal generator frequency (100 MHz to 1000 MHz)
- Replace the 180-degree splitter with a 0-degree splitter to measure common-mode signal ingress
- Repeat the above measurement sequence for common-mode ingress level on Pair A (Pins 1-2)
- Repeat the above test sequence for both differential and common-mode for cable Pair B (Pins 3-6)
- Repeat the entire above test sequence with different cable sample
- For final result differential-mode reference impedance is 100 Ω and common-mode reference impedance is 25 Ω . No level adjustment is necessary to account for splitters as they are virtually lossless (-50 dBm \rightarrow 1 mV @ 100 Ω , 500 μ V @ 25 Ω)

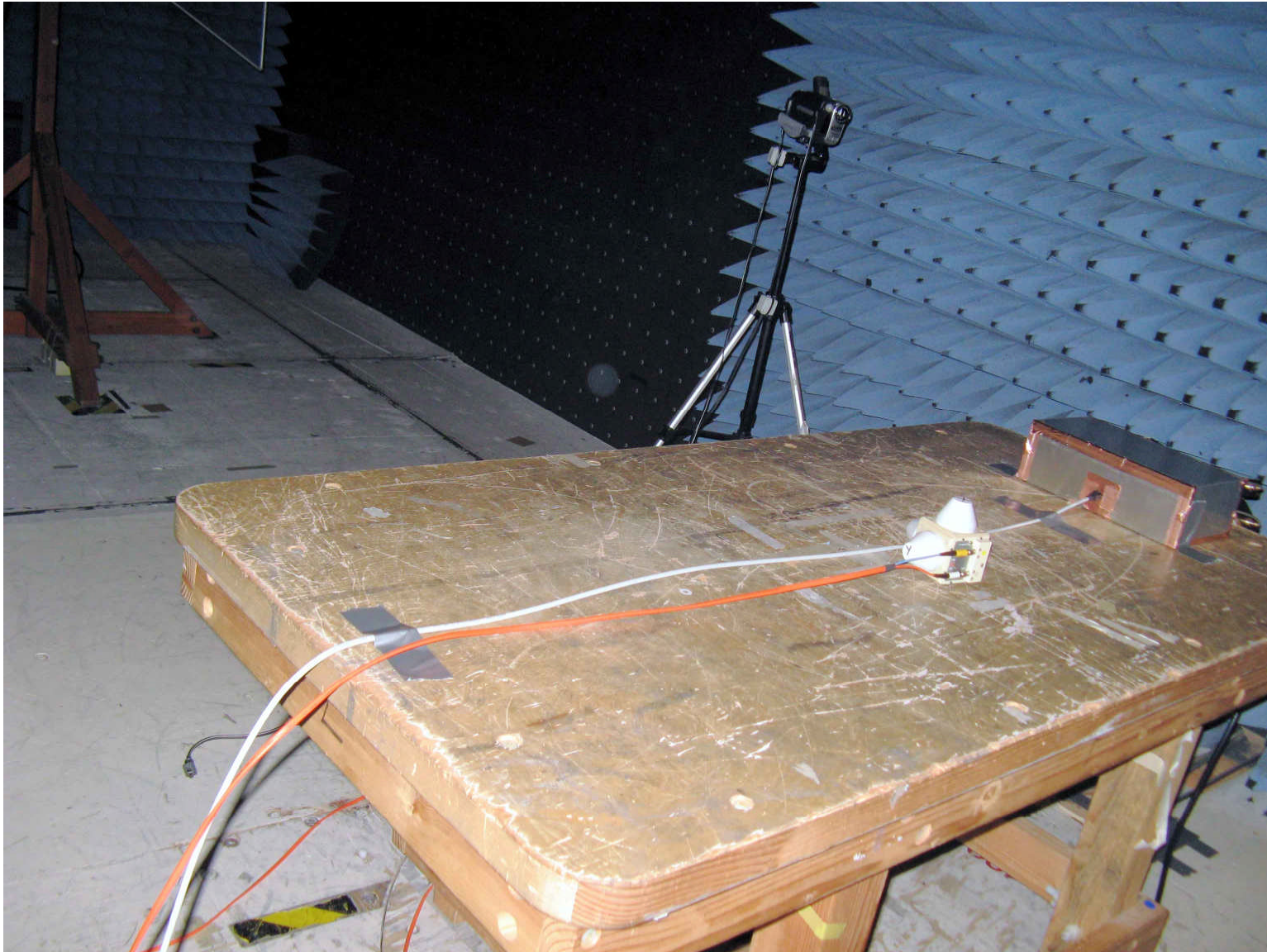
Additional data processing steps for CMNR test for 2.5G/5GBase-T

- Compute and plot differential-to-common-mode coupling ratio for Cat 6A UTP sample
- Use Cat 6A UTP common-mode measurement data to derive a CMNR common-mode target level limit

Setup to Measure Cable RF Ingress from an External Radiated Field



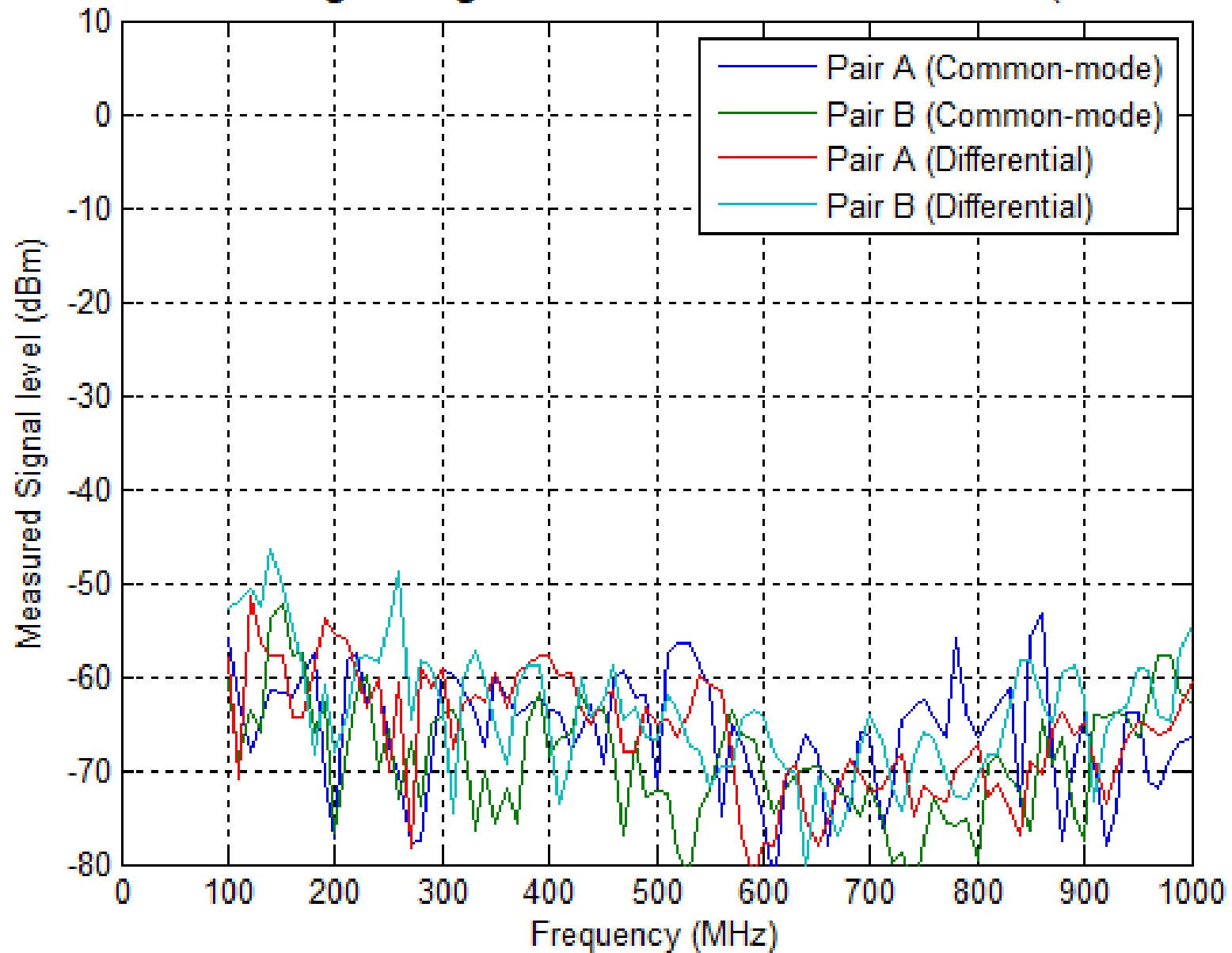
Cabling RF Ingress Measurement Test Setup (CKC Laboratories)



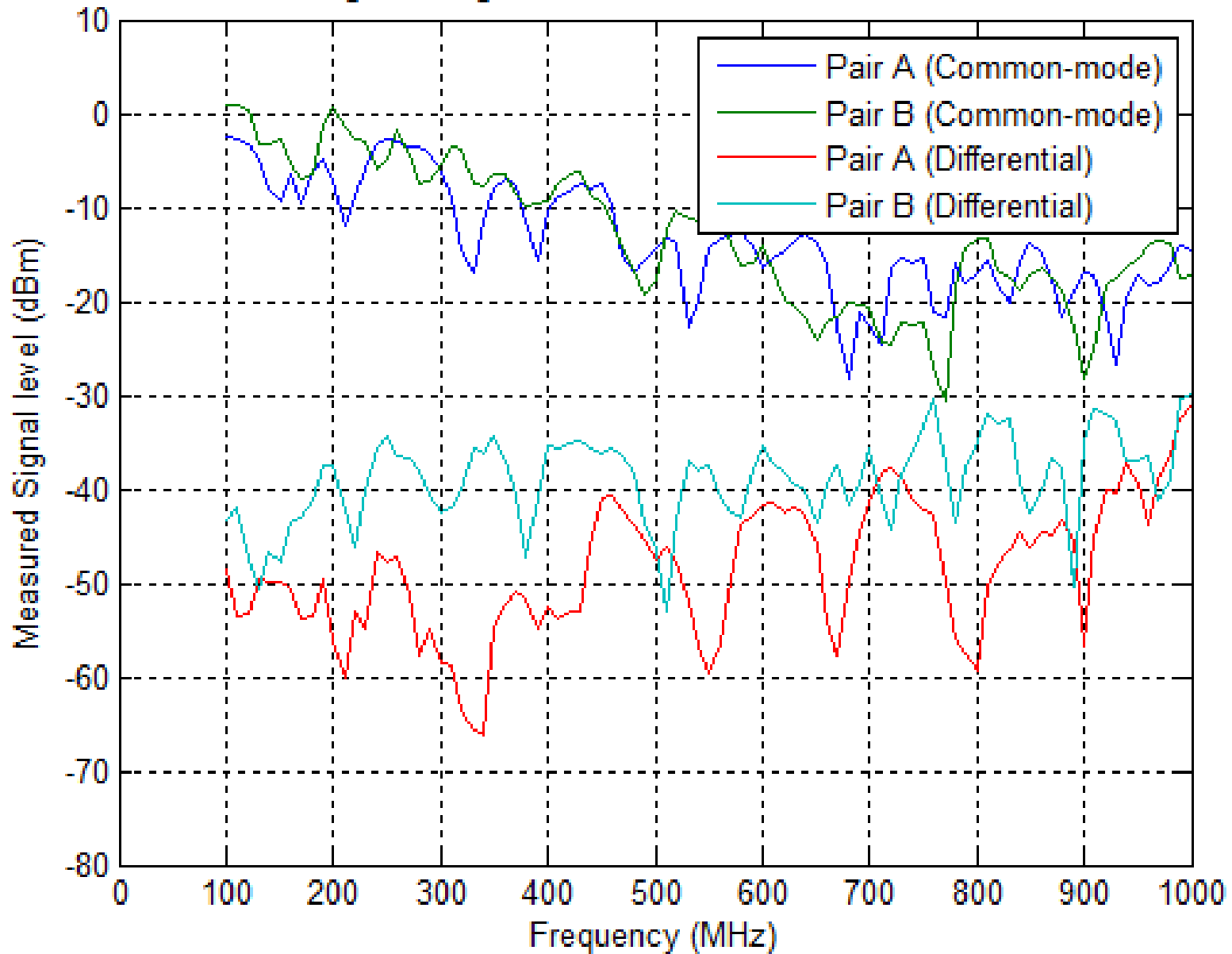
Measurement Test Cases

- Test cables
 - No cable attached to termination box (measurement noise floor)
 - Vendor A Cat 6A UTP (10 meters)
 - Vendor B Cat 6 ScTP (50 feet); screened around all four pairs, not shielded per pair
 - Vendor C Cat 6 ScTP (10 meters); screened around all four pairs, not shielded per pair
 - Vendor D Cat 6 STP (10 meters); screened around all four pairs and shielded per pair
- Plot only horizontal antenna polarization (dominant orientation)
- Total exposed cable length of 2 meters; 1.3 meters in fixed horizontal configuration
 - Simulate approximate length of cable exposed during CISPR 24 radiated immunity test (in a small chamber); note exposed length would be longer in a 10 meter chamber
- Measured both differential-mode and common-mode ingress voltage
- Measured only pairs A (pins 1-2) and B (pins 3-6) for each cable sample
- For final result differential-mode reference impedance is 100 Ω and common-mode reference impedance is 25 Ω .

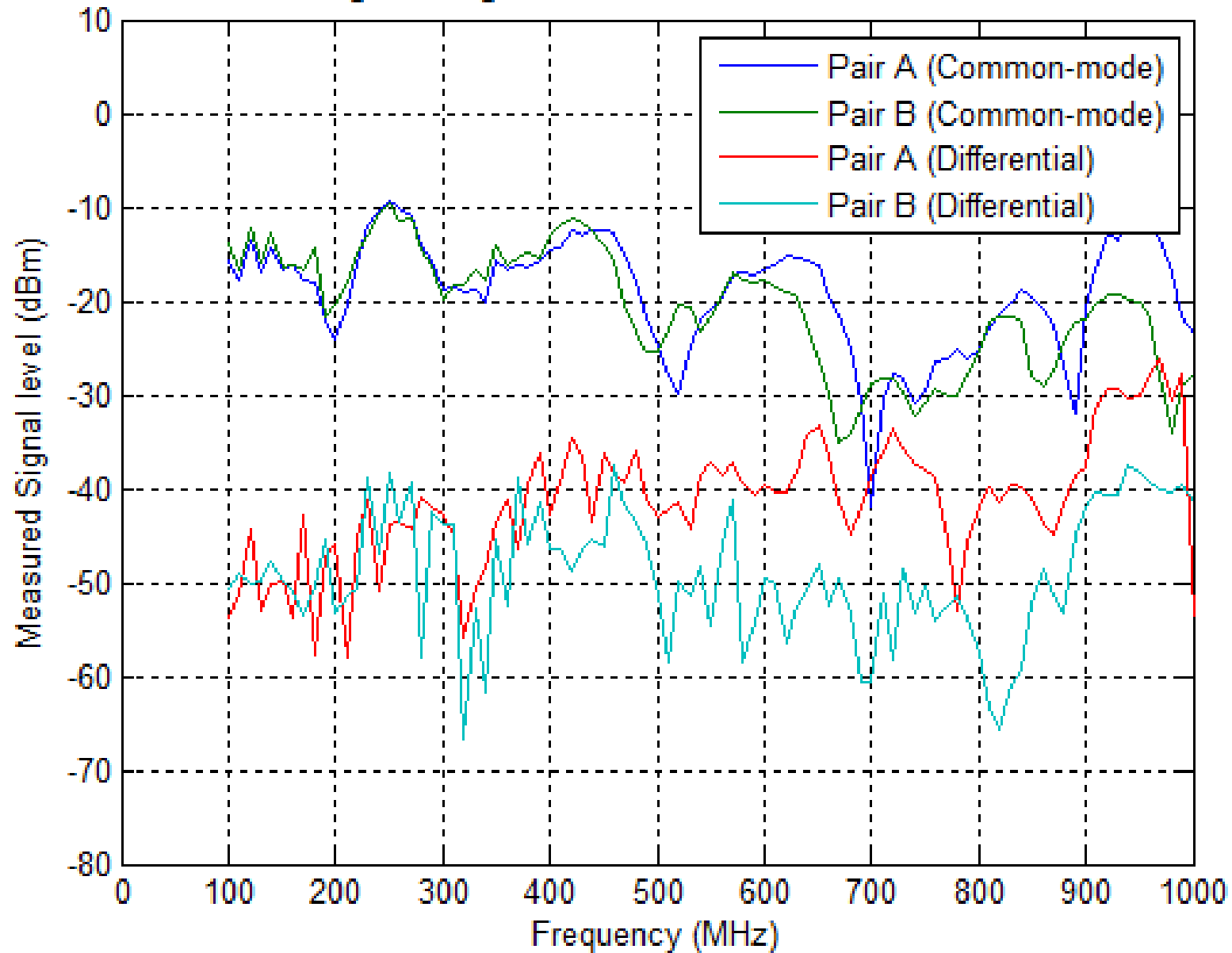
Measured RF Signal Ingress at 10V/meter: No Cable (Noise Floor)



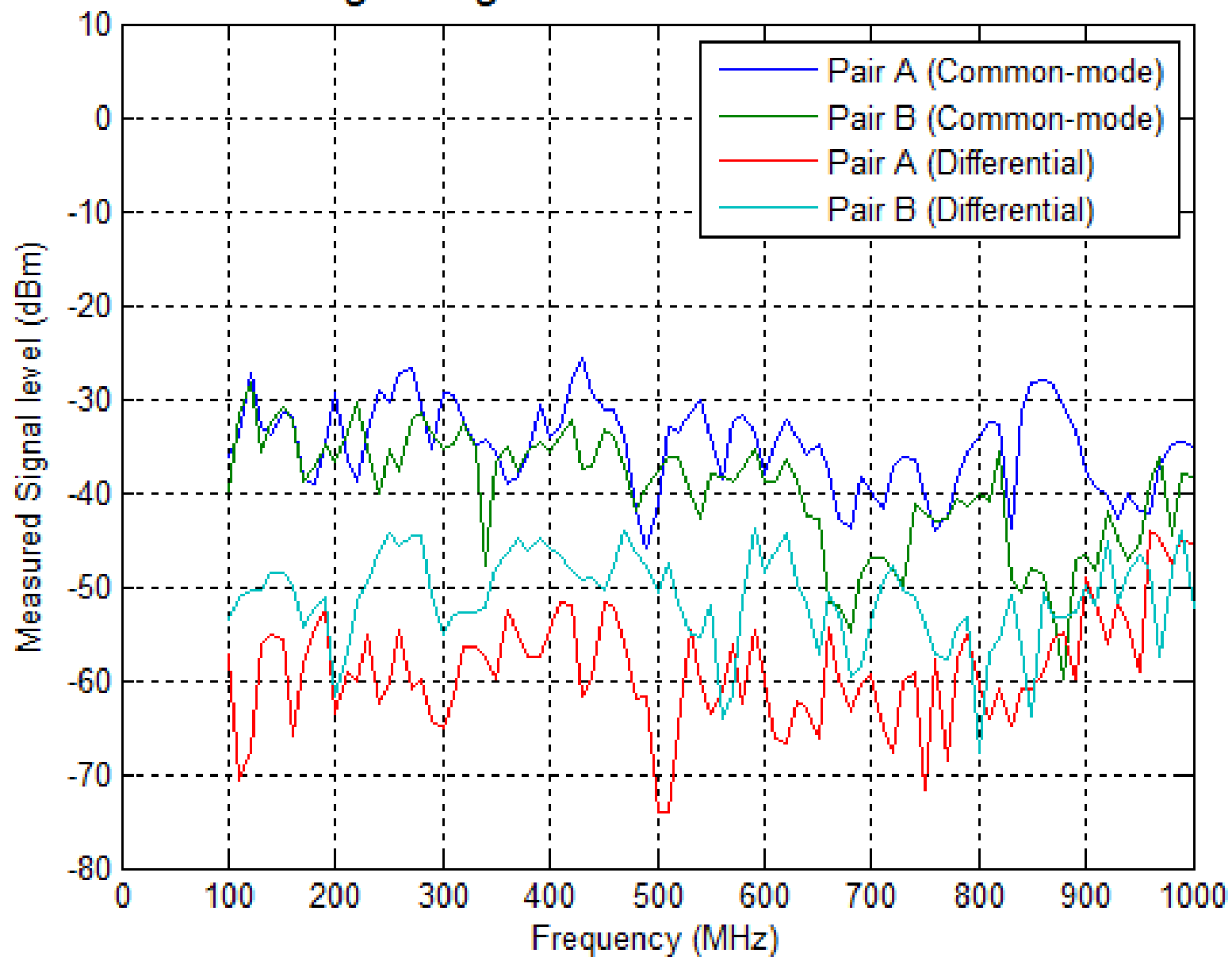
Measured RF Signal Ingress at 10V/meter: Vendor A Cat6A UTP



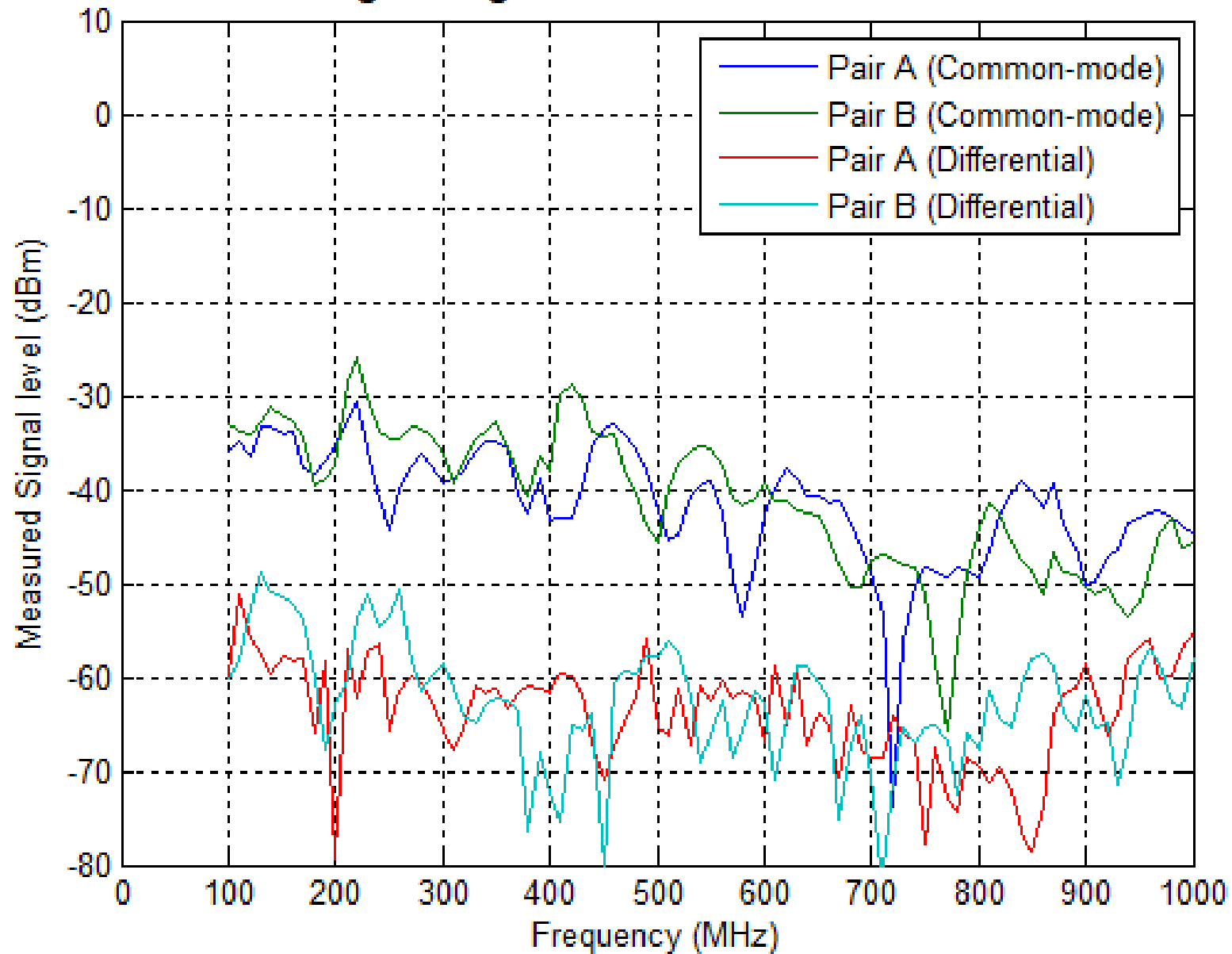
Measured RF Signal Ingress at 10V/meter: Vendor B Cat6 ScTP



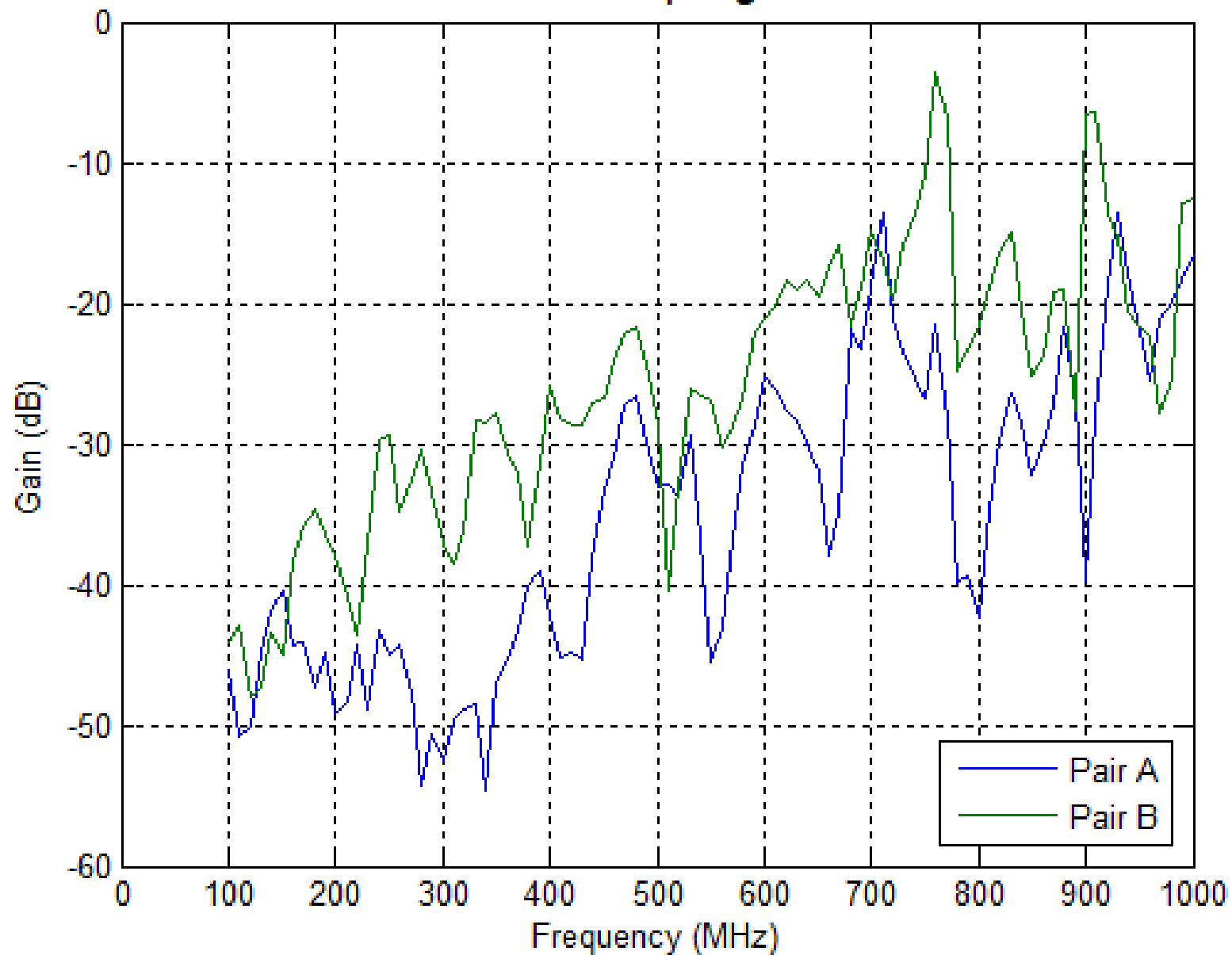
Measured RF Signal Ingress at 10V/meter: Vendor C Cat6 ScTP



Measured RF Signal Ingress at 10V/meter: Vendor D Cat6 STP



Differential-to-Common-Mode Coupling Ratio: Vendor A Cat6A UTP

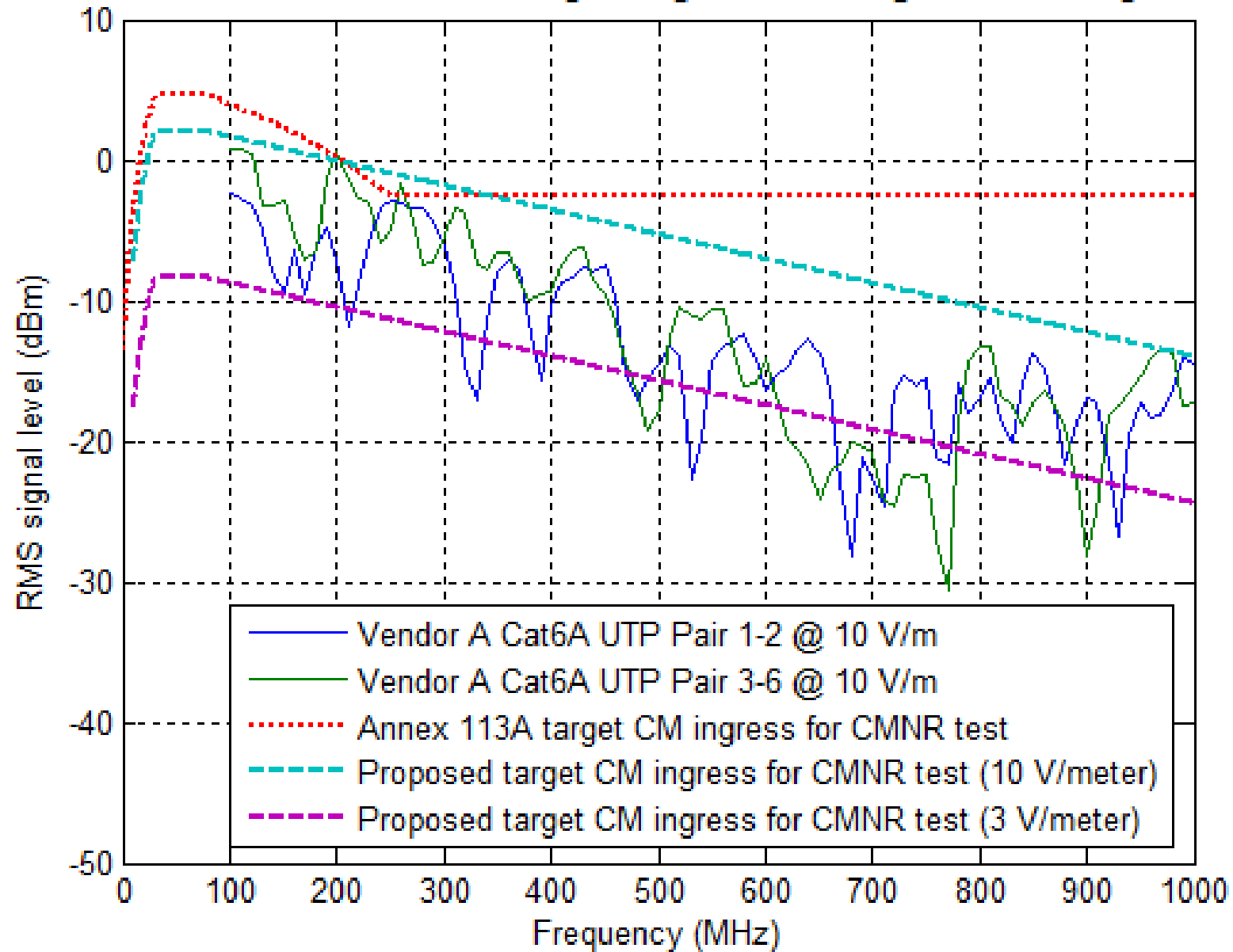


Derivation of CMNR Common-Mode Ingress Limits

- Important data is the common-mode RF ingress level as this component is generally independent of cabling category/class
- Limit line derivation for 10 MHz to 1000 MHz (intended for 802.3bz)
 - Draw a limit line across the maxima of the measured (Cat 6A) UTP common-mode data from 80 MHz to 1000 MHz
 - Add 2 dB constant offset for change of reference impedance from 25 Ohms (measurement data) to 75 Ohms (used in CMNR test for UTP, 802.3bz); +2dB shift from empirical observation of corresponding coupling change with the CC clamp
 - Extend the limit line value at 80 MHz down to 30 MHz (constant value)
 - For 10 MHz to 30 MHz, use the rolloff currently defined in Table 113A-2, but shift the result so that the value at 30 MHz matches the proposed limit line at 30 MHz
 - Shift the limit line down ~10.4 dB for the corresponding equivalent ingress levels for 3V/meter
 - Note values on the graph plot are dBm in V_{rms} , but and $V_{CM}(f)$ below is V_{pp}

$$V_{CM}(f) \leq \left\{ \begin{array}{ll} 0.01 + 0.795 \times \left(\frac{f}{30} \right) & 10 \leq f \leq 30 \\ 0.795 & 30 < f \leq 80 \\ 0.795 \times \left(10^{-0.8 \times \left(\frac{f-80}{920} \right)} \right) & 80 < f \leq 1000 \end{array} \right\} V_{pp}, f \text{ is in MHz}$$

Measured RF Common-Mode Signal Ingress vs. Target CMNR Signal Levels



Summary, Discussion Points, Next Steps

- Proposed CMNR CM target levels (measured during clamp validation step) from measured RF ingress levels in an anechoic chamber with a 10 V/meter external field near the MDI port
 - This result is from a set of data points using a simple and common cable configuration
- **While the common-mode target limit line in this contribution may not be adopted, an important observation from this contribution is that the common-mode ingress level should roll off with increasing frequency and should not remain constant above 250 MHz as currently defined in Table 113A-2**
 - High-frequency rolloff likely due to re-radiation into space of received RF ingress signal (scattering); greater effect at higher frequencies and at points on the cable farther from the MDI port
 - Most RF ingress from “received” signals (field-to-cable coupling) near the MDI port termination
 - Rolloff characteristic may change in the presence of “slack loops” or other unusual cable layout geometries (e.g. Bech rack), especially if the unusual feature is located near the MDI port
- Screened cables are NOT alike in RF ingress performance
 - Vendor B Cat 6 ScTP was no better than Cat6A UTP above 100 MHz (differential signal ingress)
 - Performance differences due to differences in outer shield coverage and connector termination (full 360-degree for good ScTP cables, pigtail for bad ScTP cable)
- Should the CMNR test adopt a common-mode ingress target level equivalent to a 3V/meter external field or a 10V/meter external field ?
 - Most 10GBase-T testing with UTP used 3V/meter, but some customers wanted specific frequencies tested at 10V/meter; at 10V/meter the test pass criterion may be different
 - Annex 113A specifies the test channel as maximal insertion loss within link segment specification
- Need to derive a corresponding differential mode RF ingress limit