Common-Mode Impulse Noise Measurements

April 21, 2015

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Overview

- **Purpose:** To measure the common-mode component of impulse noise induced on cable by nearby ESD events and switch contact arc events
- Discuss the need for common-mode measurements
- Common-mode measurement test setup
- Initial test results:
  - Tables, PSD and waveform plots
- Observations
  - Example impulse noise test setup with split signal paths
  - Measured splitter/balun common-mode rejection
- Discuss next steps

Need for Common-Mode Impulse Noise Measurements

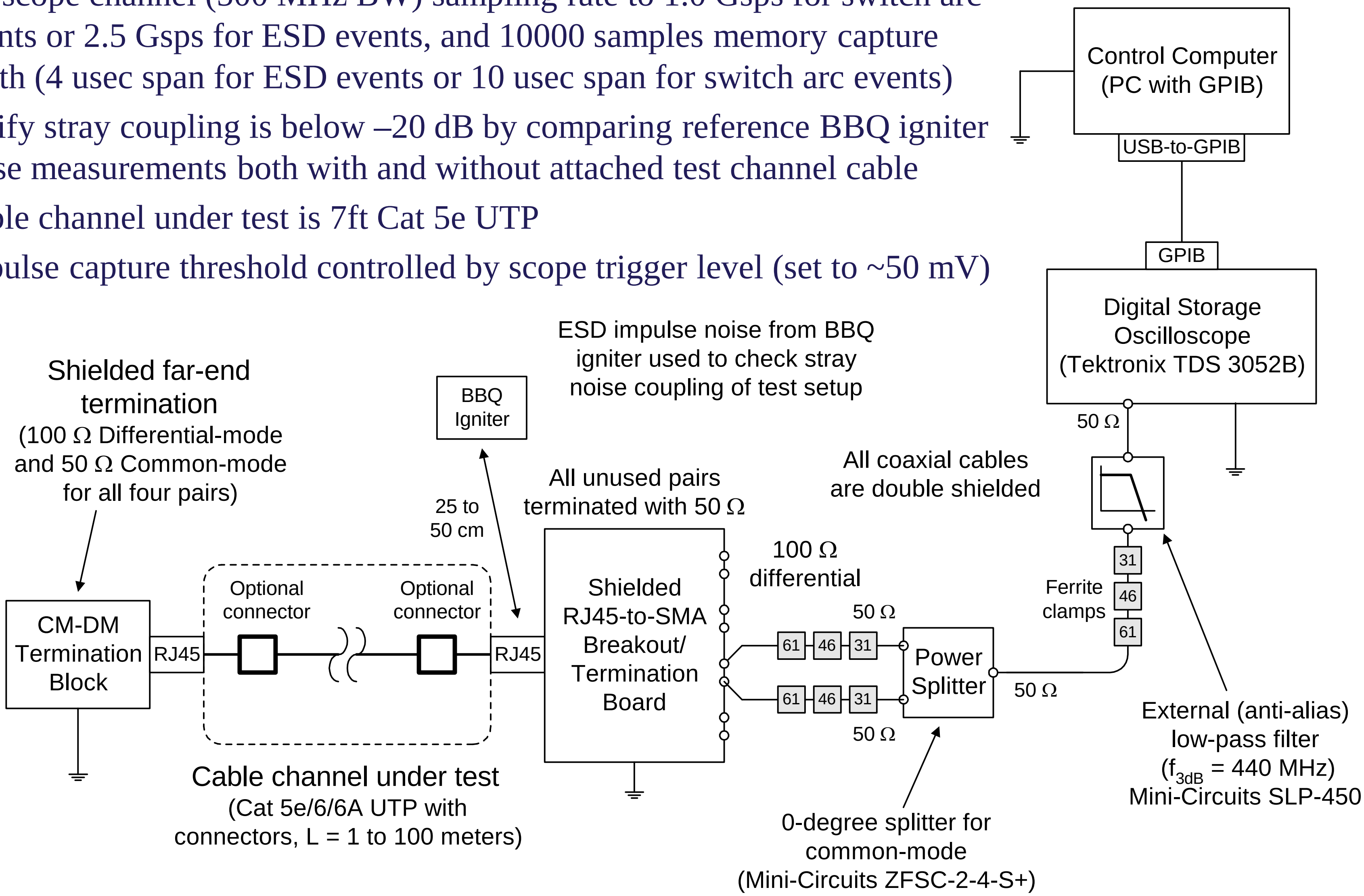
- Impulse noise is radiation-coupled into link cabling primarily as a common-mode signal which is converted into the differential disturbance seen at the receiver by imbalance within the transmission channel before the MDI port transformer

- Motivation for common-mode measurement
  - Measurement data to design (common-mode) test signals for impulse noise immunity test procedures
  - Data useful in determining transformer/front-end common-mode rejection requirements

- How strong is the common-mode signal with respect to the differential signal and how does it affect our test methods?
  - How much common-mode rejection is required in the differential test fixture signal path (i.e. splitter/balun) to prevent any common-mode “leakage” errors during differential impulse noise measurements?
  - How much dynamic range is required to create a test setup that can resolve common-mode and differential-mode signal components simultaneously from the same event?

Common-Mode Impulse Noise Event Measurement Test Setup

- Set scope channel (500 MHz BW) sampling rate to 1.0 Gsps for switch arc events or 2.5 Gsps for ESD events, and 10000 samples memory capture depth (4 usec span for ESD events or 10 usec span for switch arc events)
- Verify stray coupling is below –20 dB by comparing reference BBQ igniter noise measurements both with and without attached test channel cable
- Cable channel under test is 7ft Cat 5e UTP
- Impulse capture threshold controlled by scope trigger level (set to ~50 mV)



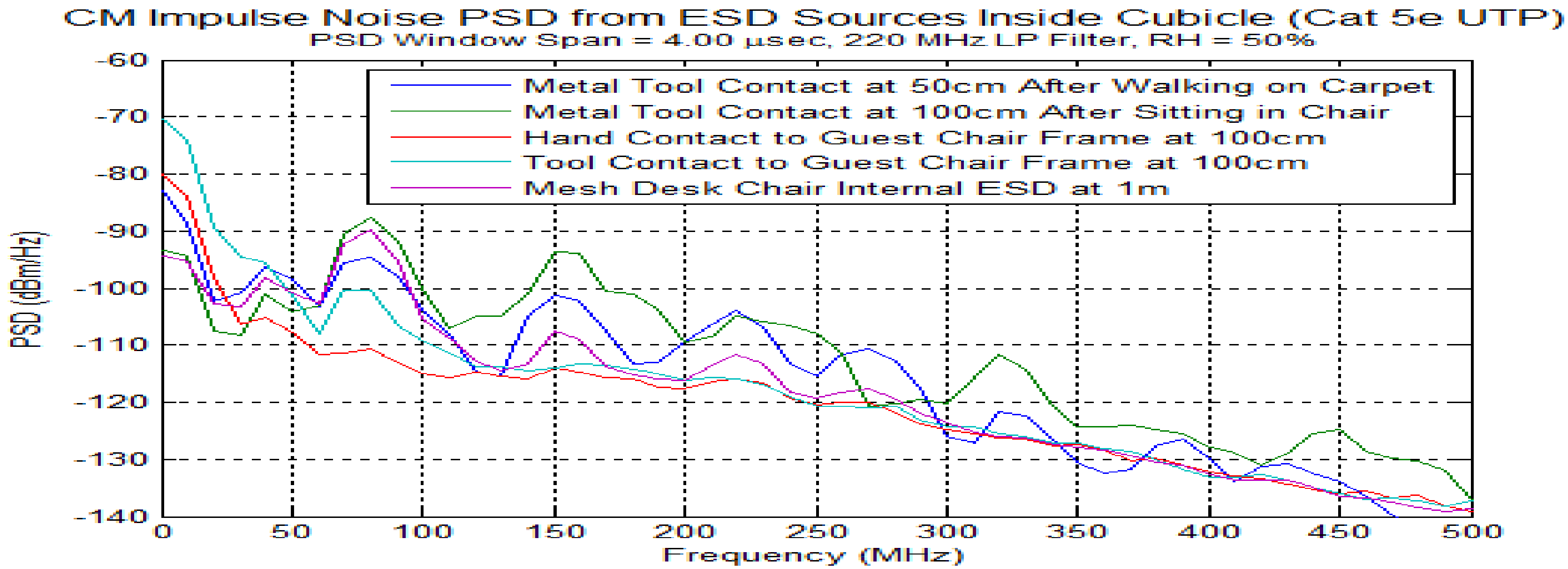
Implementation of Measurement Test Setup

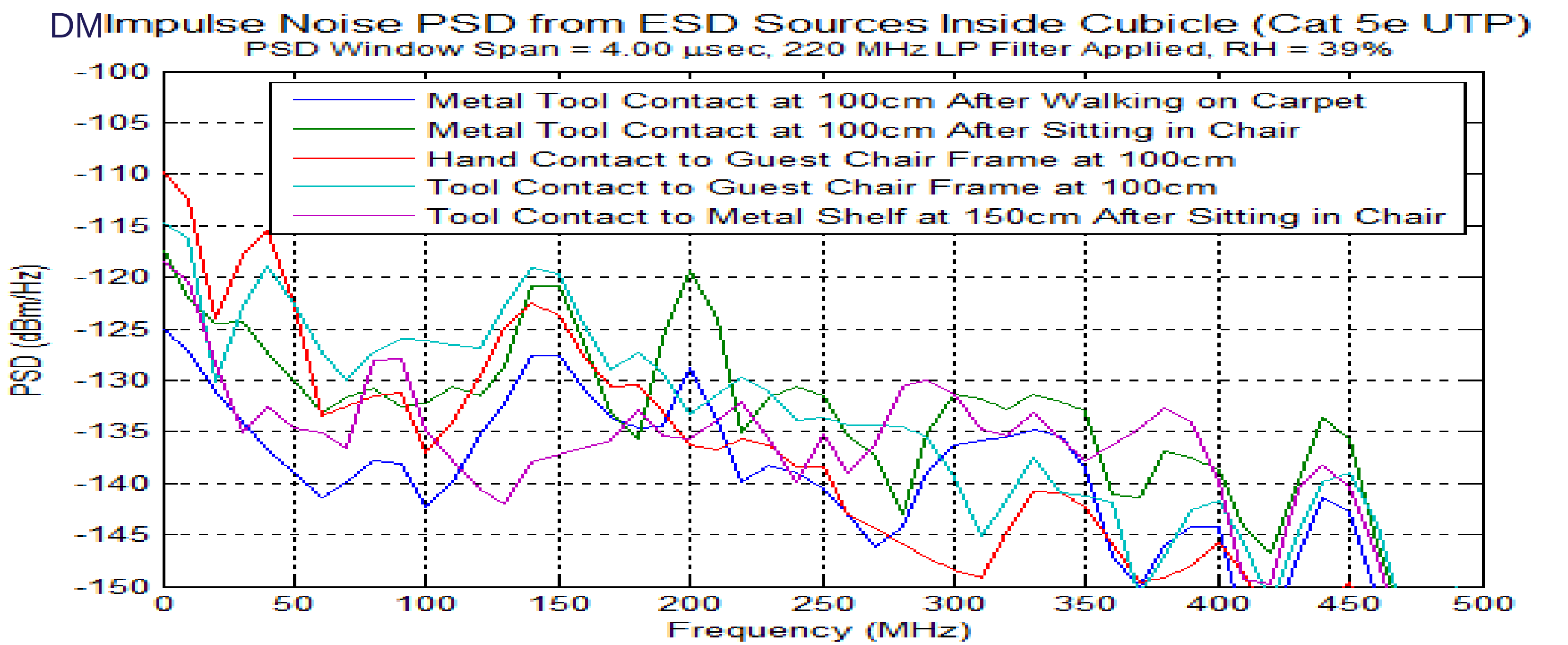
Comparison of Common-Mode vs Differential ESD-Based Impulse Noise Measurements from Cubicle (After 220 MHz Lowpass Filter)

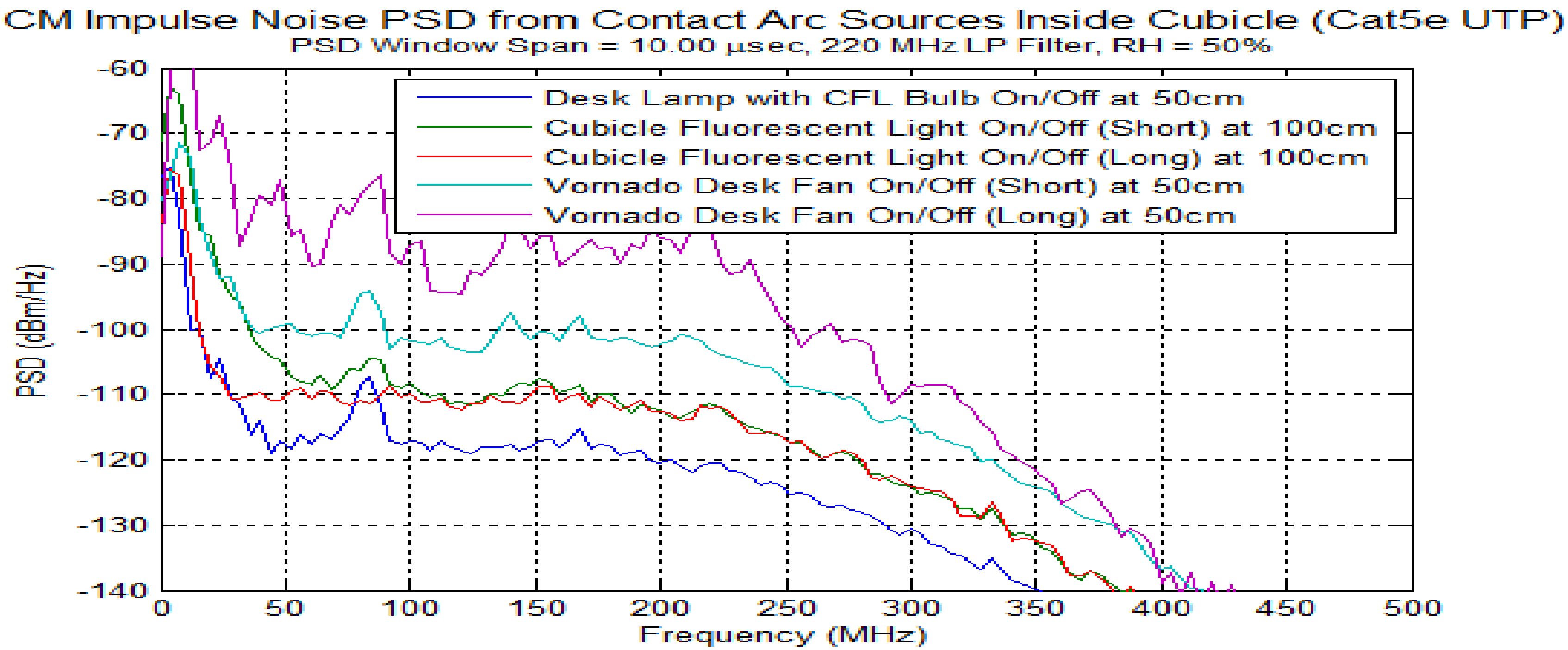
Cat 5e UTP	Common-Mode		Differential-Mode	
Description of Event	Peak-to-peak voltage (mV)	Time span (nsec)	Peak-to-peak voltage (mV)	Time span (nsec)
	Relative humidity = 50 pct		*Relative humidity = 39 pct*	
Metal Tool Contact at 50cm After Walking on Carpet	1475.74	536.0	39.75	71.2
Metal Tool Contact at 100cm After Walking on Carpet	630.29	336.0	39.83	62.8
Metal Tool Contact at 50cm After Sitting in Chair	4387.20	536.8	100.27	83.6
Metal Tool Contact at 100cm After Sitting in Chair	2453.33	163.2	98.28	92.0
Hand Contact to Guest Chair Frame at 100cm	1004.93	528.4	85.58	216.8
Tool Contact to Guest Chair Frame at 100cm	2833.74	634.0	113.83	190.0
Tool Contact to Metal Shelf at 150cm After Sitting in Chair	2727.44	366.4	52.08	164.0
Mesh Desk Chair Internal ESD at 1m	1332.52	268.4	107.42	52.8
Note: The common-mode and differential-mode values shown for each event are <u>not</u> from the same identical impulse noise event. This table is intended to illustrate the magnitude of the difference.				

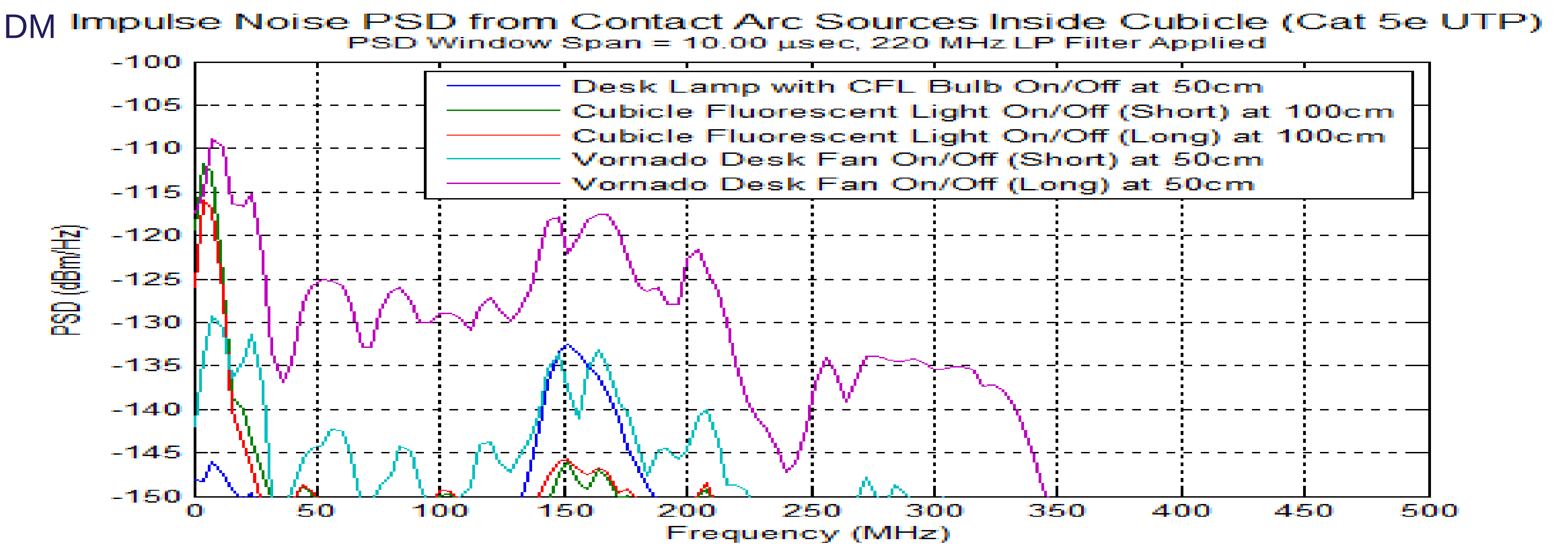
Comparison of Common-Mode vs Differential Contact Arc Impulse Noise Measurements from Cubicle (After 220 MHz Lowpass Filter)

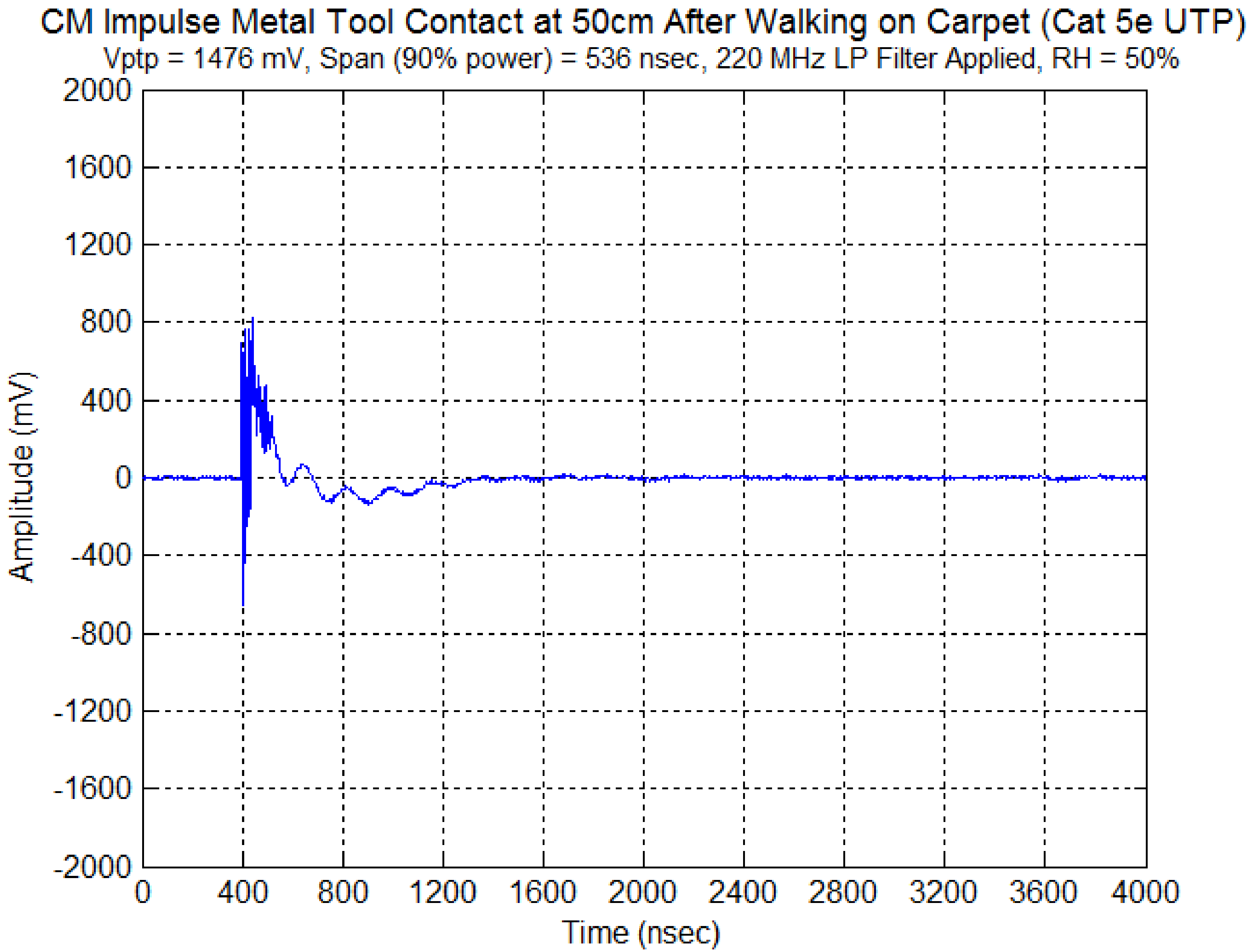
Cat 5e UTP	Common-Mode		Differential-Mode	
Description of Event	**Peak-to-peak voltage (mV)**	**Time span (nsec)**	**Peak-to-peak voltage (mV)**	**Time span (nsec)**
	Relative humidity = 50 pct		*Relative humidity = 39 pct*	
Desk Lamp with CFL Bulb On/Off at 50cm	1662.28	3016.0	15.70	45.0
Desk Lamp with LED Bulb On/Off at 50cm	693.56	2082.0	8.65	573.0
Desk Lamp with Incandescent Bulb On/Off at 50cm	744.26	1159.0	6.25	43.0
Cubicle Fluorescent Light On/Off at 100cm (short event)	7264.29	903.0	33.92	840.0
Cubicle Fluorescent Light On/Off at 100cm (long event)	2319.09	5881.0	10.66	8608.0
Vornado Desk Fan On/Off at 50cm (short event)	5916.26	302.0	18.59	170.0
Vornado Desk Fan On/Off at 50cm (long event)	7426.15	7871.0	45.47	6168.0
Note: The common-mode and differential-mode values shown for each event are not from the same identical impulse noise event. This table is intended to illustrate the magnitude of the difference.				

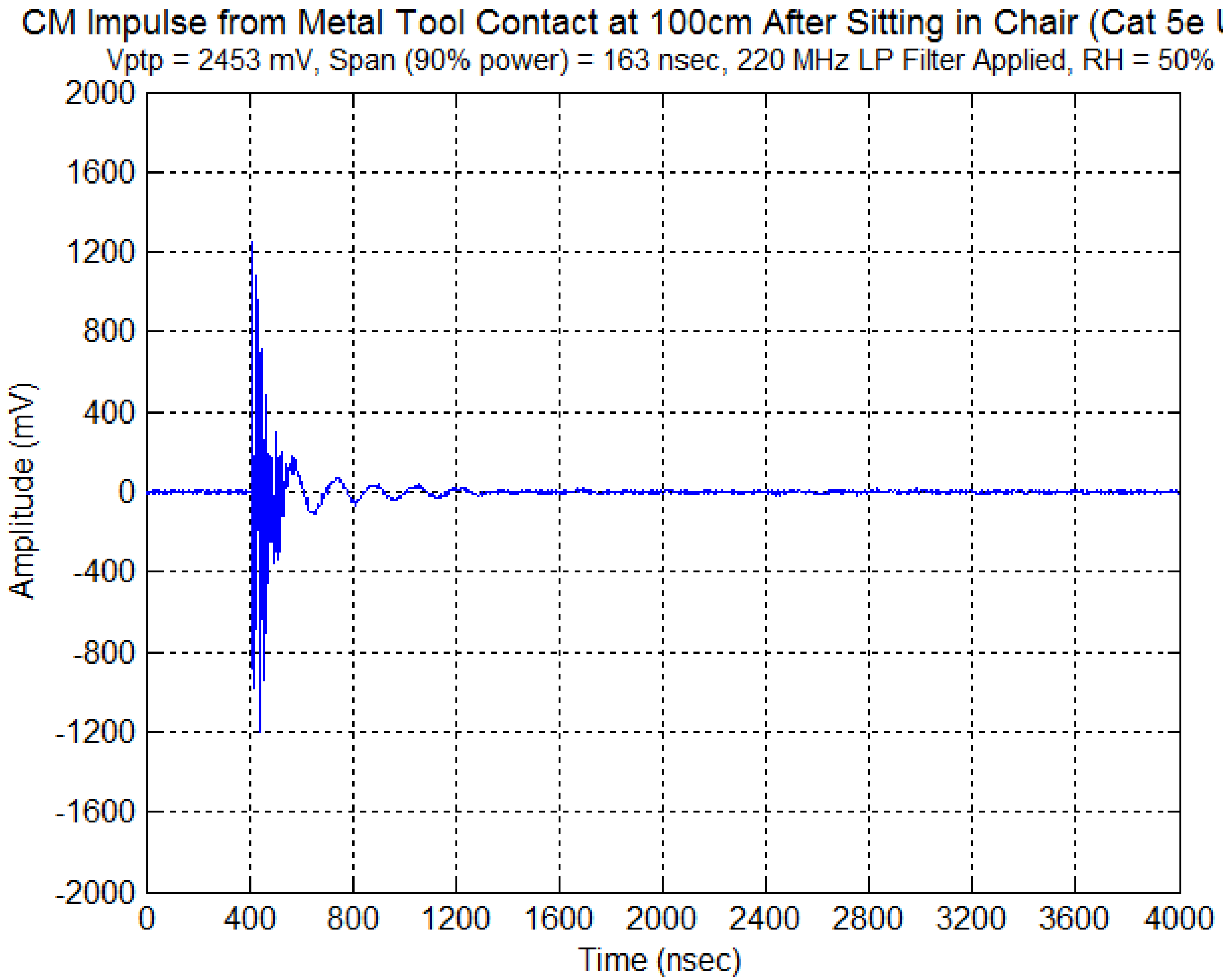

CM Impulse Noise PSD from ESD Sources Inside Cubicle (Cat 5e UTP)
PSD Window Span = 4.00 µsec, 220 MHz LP Filter, RH = 50%
Metal Tool Contact at 50cm After Walking on Carpet
Metal Tool Contact at 100cm After Sitting in Chair
Hand Contact to Guest Chair Frame at 100cm
Tool Contact to Guest Chair Frame at 100cm
Mesh Desk Chair Internal ESD at 1m
PSD (dBm/Hz)
-60
-70
-80
-90
-100
-110
-120
-130
-140
0
50
100
150
200
250
300
350
400
450
500
Frequency (MHz)

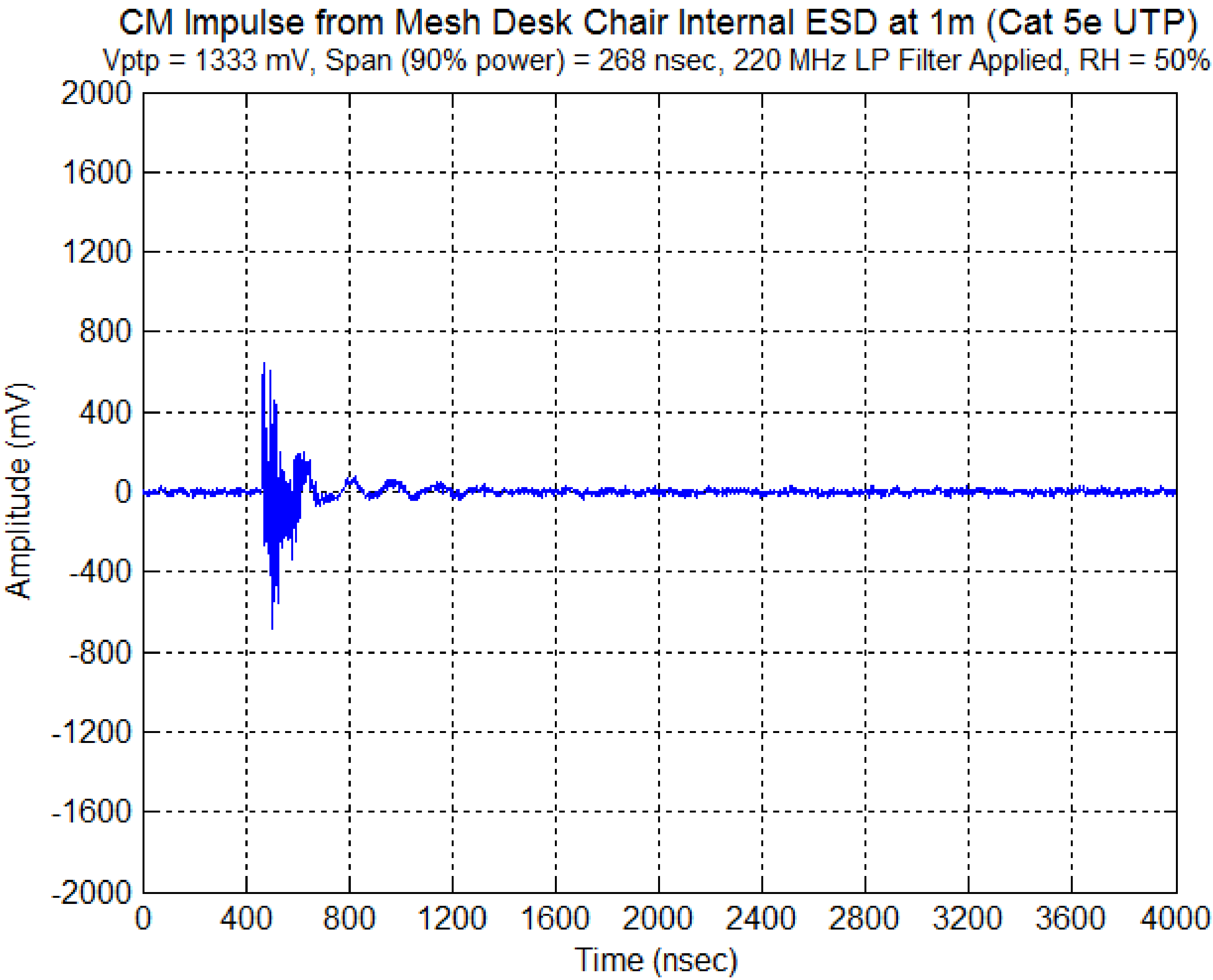

DM Impulse Noise PSD from ESD Sources Inside Cubicle (Cat 5e UTP)
PSD Window Span = 4.00 µsec, 220 MHz LP Filter Applied, RH = 39%
Metal Tool Contact at 100cm After Walking on Carpet
Metal Tool Contact at 100cm After Sitting in Chair
Hand Contact to Guest Chair Frame at 100cm
Tool Contact to Guest Chair Frame at 100cm
Tool Contact to Metal Shelf at 150cm After Sitting in Chair
PSD (dBm/Hz)
-100
-105
-110
-115
-120
-125
-130
-135
-140
-145
-150
0
50
100
150
200
250
300
350
400
450
500
Frequency (MHz)

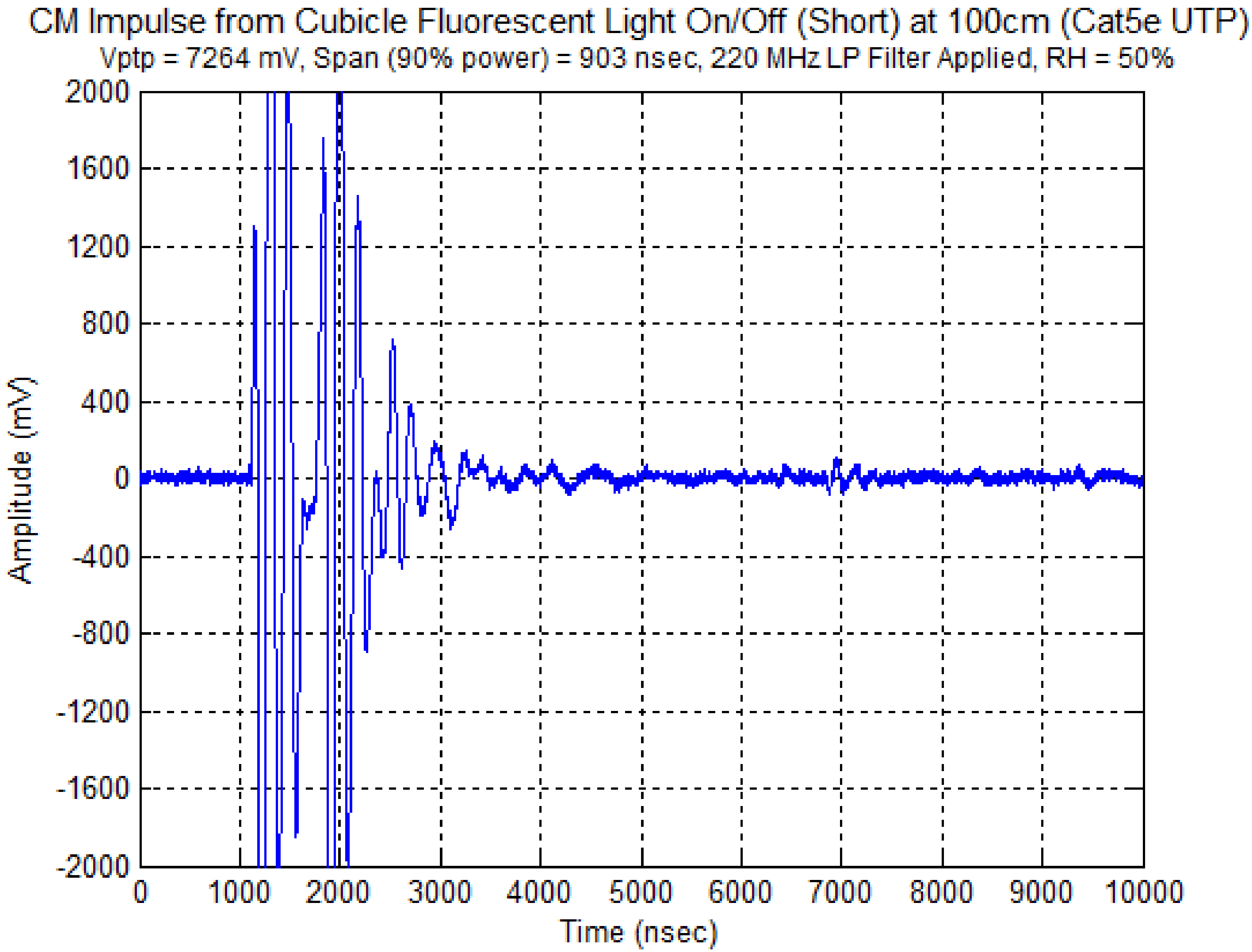

CM Impulse Noise PSD from Contact Arc Sources Inside Cubicle (Cat5e UTP)
PSD Window Span = 10.00 µsec, 220 MHz LP Filter, RH = 50%
Desk Lamp with CFL Bulb On/Off at 50cm
Cubicle Fluorescent Light On/Off (Short) at 100cm
Cubicle Fluorescent Light On/Off (Long) at 100cm
Vornado Desk Fan On/Off (Short) at 50cm
Vornado Desk Fan On/Off (Long) at 50cm
PSD (dBm/Hz)
Frequency (MHz)


DM
Impulse Noise PSD from Contact Arc Sources Inside Cubicle (Cat 5e UTP)
PSD Window Span = 10.00 µsec, 220 MHz LP Filter Applied
Desk Lamp with CFL Bulb On/Off at 50cm
Cubicle Fluorescent Light On/Off (Short) at 100cm
Cubicle Fluorescent Light On/Off (Long) at 100cm
Vornado Desk Fan On/Off (Short) at 50cm
Vornado Desk Fan On/Off (Long) at 50cm
PSD (dBm/Hz)
Frequency (MHz)


CM Impulse Metal Tool Contact at 50cm After Walking on Carpet (Cat 5e UTP)
Vptp = 1476 mV, Span (90% power) = 536 nsec, 220 MHz LP Filter Applied, RH = 50%
Amplitude (mV)
2000
1600
1200
800
400
0
-400
-800
-1200
-1600
-2000
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
Time (nsec)


CM Impulse from Metal Tool Contact at 100cm After Sitting in Chair (Cat 5e UTP)
Vptp = 2453 mV, Span (90% power) = 163 nsec, 220 MHz LP Filter Applied, RH = 50%
Amplitude (mV)
2000
1600
1200
800
400
0
-400
-800
-1200
-1600
-2000
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
Time (nsec)


CM Impulse from Mesh Desk Chair Internal ESD at 1m (Cat 5e UTP)
Vptp = 1333 mV, Span (90% power) = 268 nsec, 220 MHz LP Filter Applied, RH = 50%
Amplitude (mV)
2000
1600
1200
800
400
0
-400
-800
-1200
-1600
-2000
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
Time (nsec)


CM Impulse from Cubicle Fluorescent Light On/Off (Short) at 100cm (Cat5e UTP)
Vptp = 7264 mV, Span (90% power) = 903 nsec, 220 MHz LP Filter Applied, RH = 50%
Amplitude (mV)
2000
1600
1200
800
400
0
-400
-800
-1200
-1600
-2000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Time (nsec)

Observations

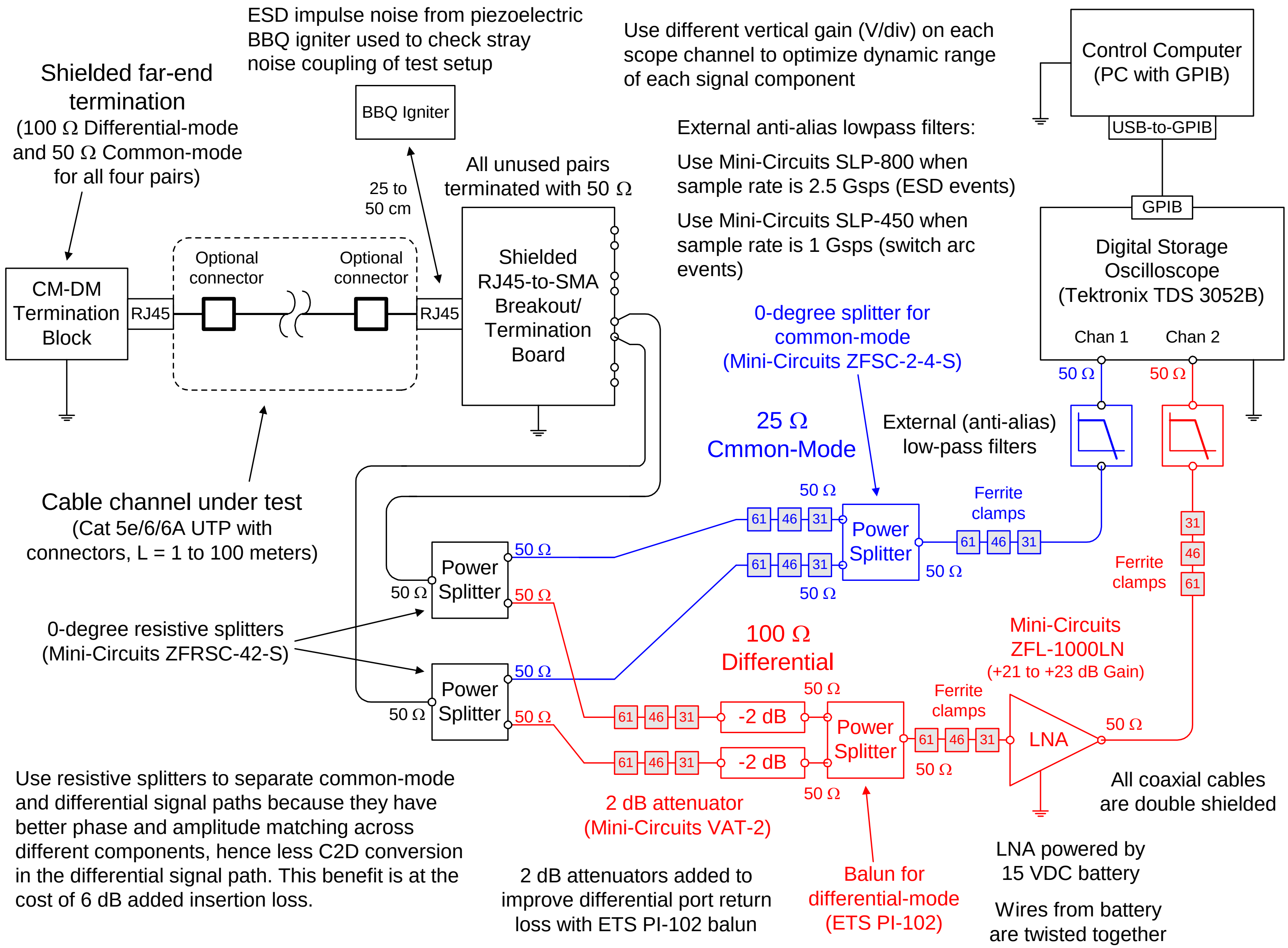
- Since the designated common-mode reference impedance at the MDI port is 50 Ohms, no post-process scaling of the signal is required because the 0-degree splitter provides the +3 dB scaling to convert from the 25 Ohms test setup common-mode impedance

- Common-mode impulses from ESD events can be greater than 4 V peak-to-peak; common-mode impulses from switch contact arc events can be greater than 7 V peak-to-peak
  - Most energy from switch contact arc events is below 10 MHz

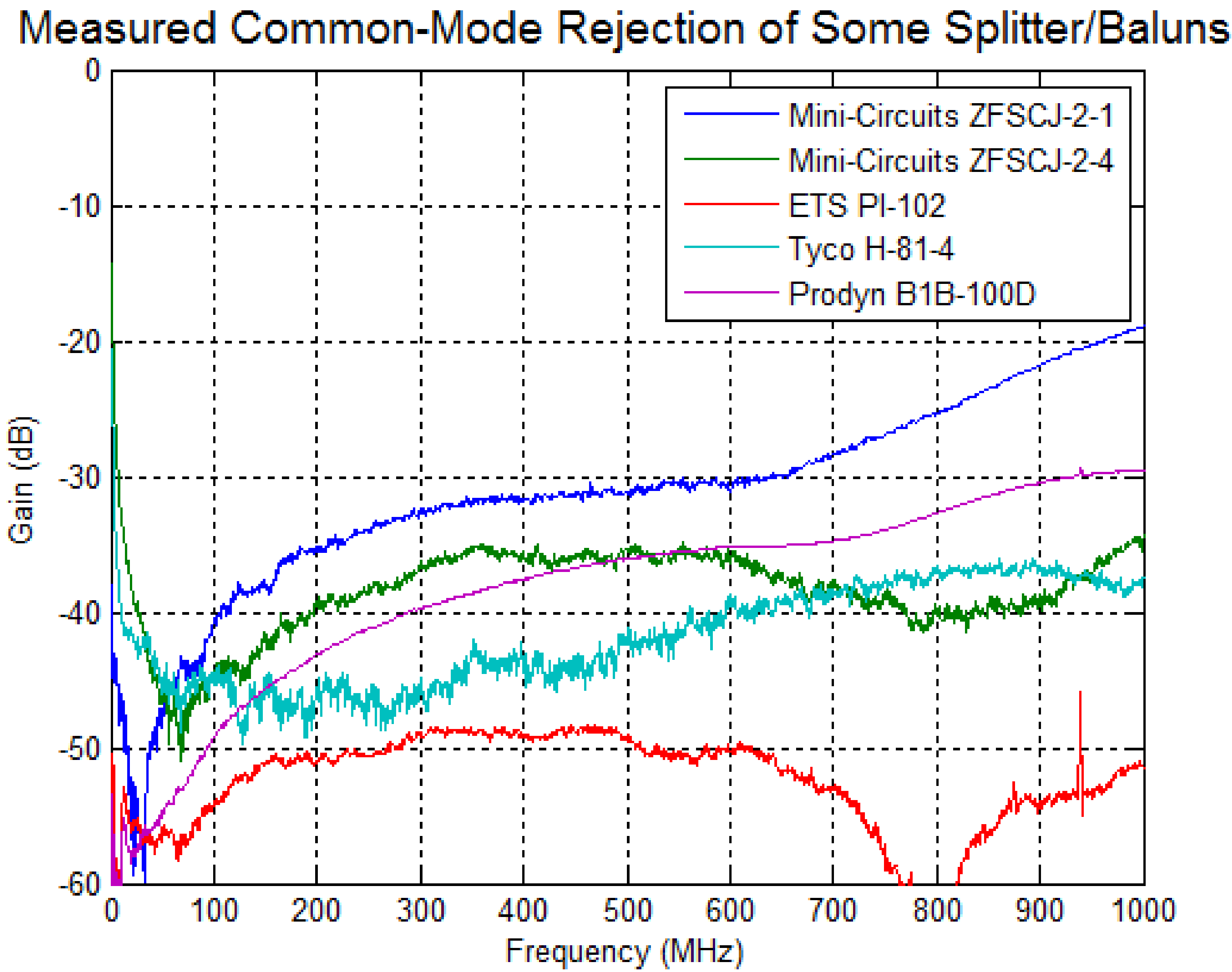
- Extracting differential signals down to 1 mV resolution by direct scope channel subtraction requires a scope input channel dynamic range > 12 bits (no averaging) at a sample rate of at least 2.5 Gsps (for ESD events)
  - Better test setup solution (and less expensive) to simultaneously observe both signal components is to split the impulse noise event into separate common-mode and differential signal paths

- Ideally, a differential splitter/balun should provide > 50 dB common-mode rejection below 20 MHz and at least 30 dB up to 500 MHz to prevent common-mode "leakage" and measurement error of the differential signal component

Example Impulse Noise Test Setup with Split Signal Paths



Use resistive splitters to separate common-mode and differential signal paths because they have better phase and amplitude matching across different components, hence less C2D conversion in the differential signal path. This benefit is at the cost of 6 dB added insertion loss.


Measured Common-Mode Rejection of Some Splitter/Baluns
Mini-Circuits ZFSCJ-2-1
Mini-Circuits ZFSCJ-2-4
ETS PI-102
Tyco H-81-4
Prodyn B1B-100D
Gain (dB)
0
-10
-20
-30
-40
-50
-60
0
100
200
300
400
500
600
700
800
900
1000
Frequency (MHz)

Next Steps

- Simultaneous capture of both common-mode and differential components of impulse noise from same event
  - Detect any useful relationships
- Determine if common-mode coupling can generate reproducible differential impulse noise disturbances for test purposes
  - Common-mode clamp coupling is desirable because it creates the least amount of structural distortion to an existing channel
- Discussion of useful results to bring