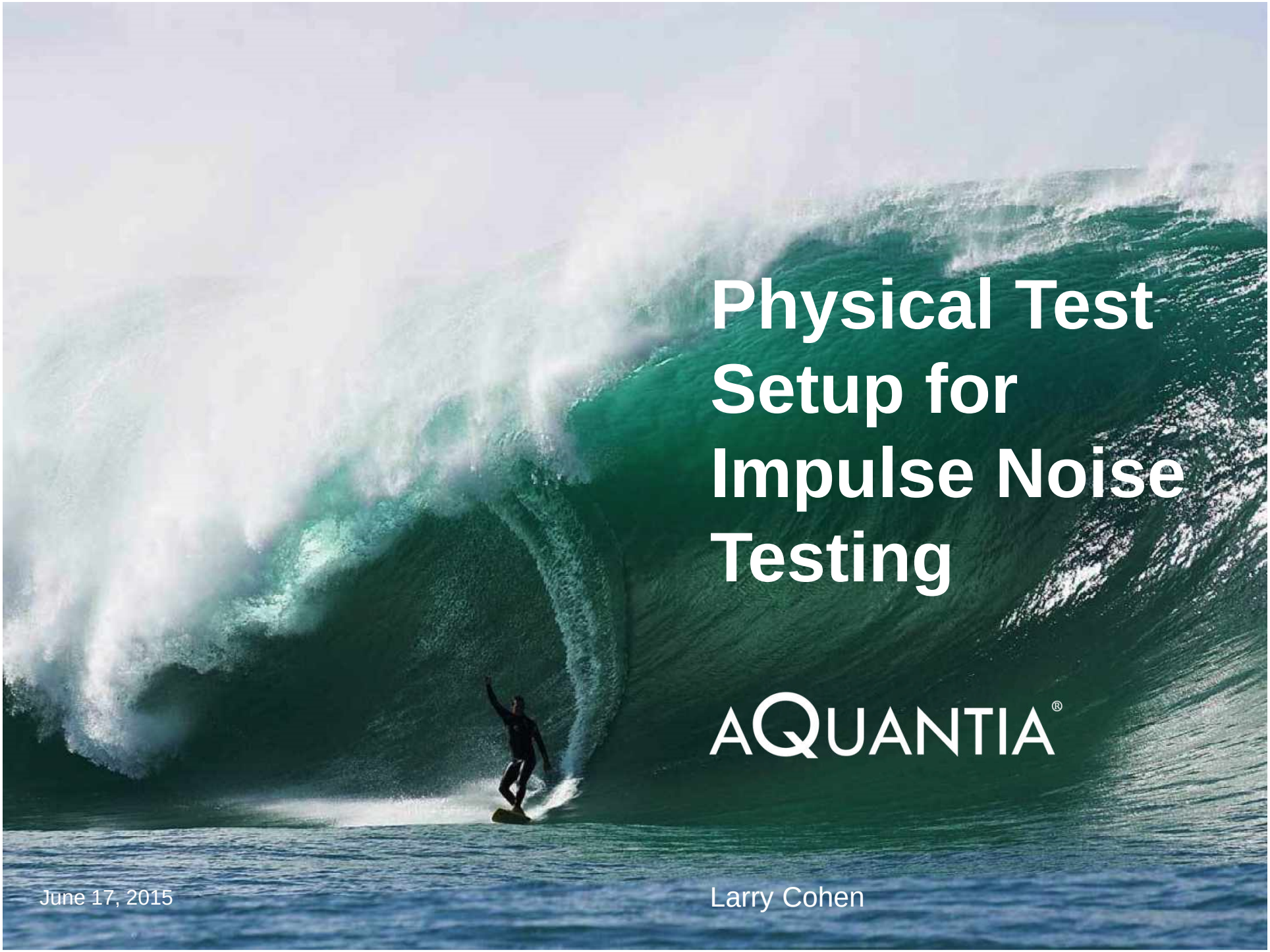

Physical Test Setup for Impulse Noise Testing

AQUANTIA®

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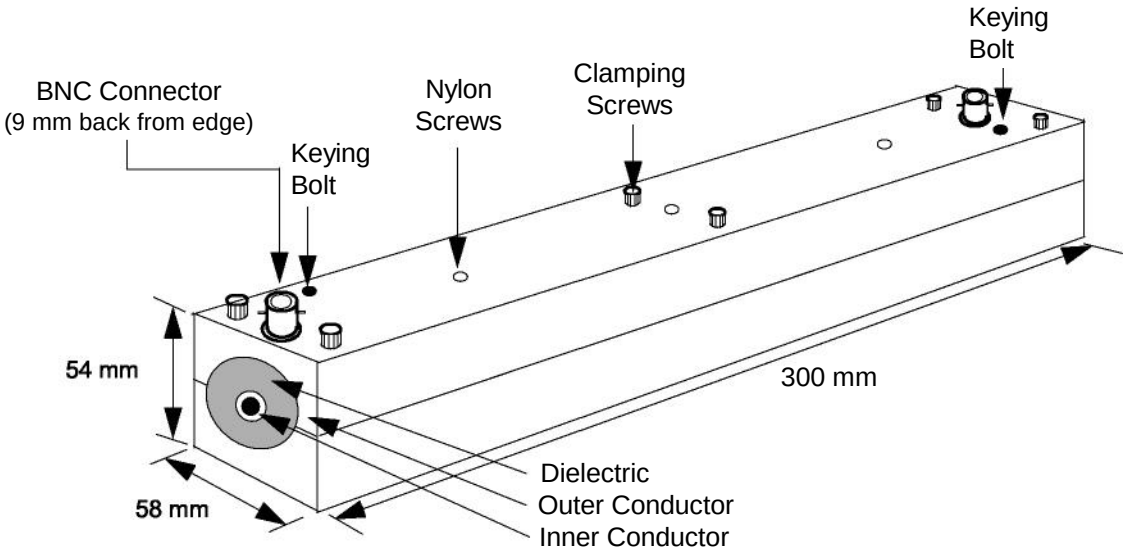
Overview

- **Purpose:** Use measurement results for the EM coupling (Campbell) clamp to determine a stable physical test setup for impulse noise testing.
  - Define a test setup diagram for the standard that will allow use of the clamp up to 1000 MHz (allows additional use for radiated immunity testing)
- Overview of EM coupling (Campbell) clamp
- Test setups for EM clamp impulse noise testing and characterization of the EM clamp
- Presentation of measurement data for various clamp configurations
- Observations for stable clamp operation
- Next steps and discussion points

Overview of the EM Coupling (Campbell) Clamp

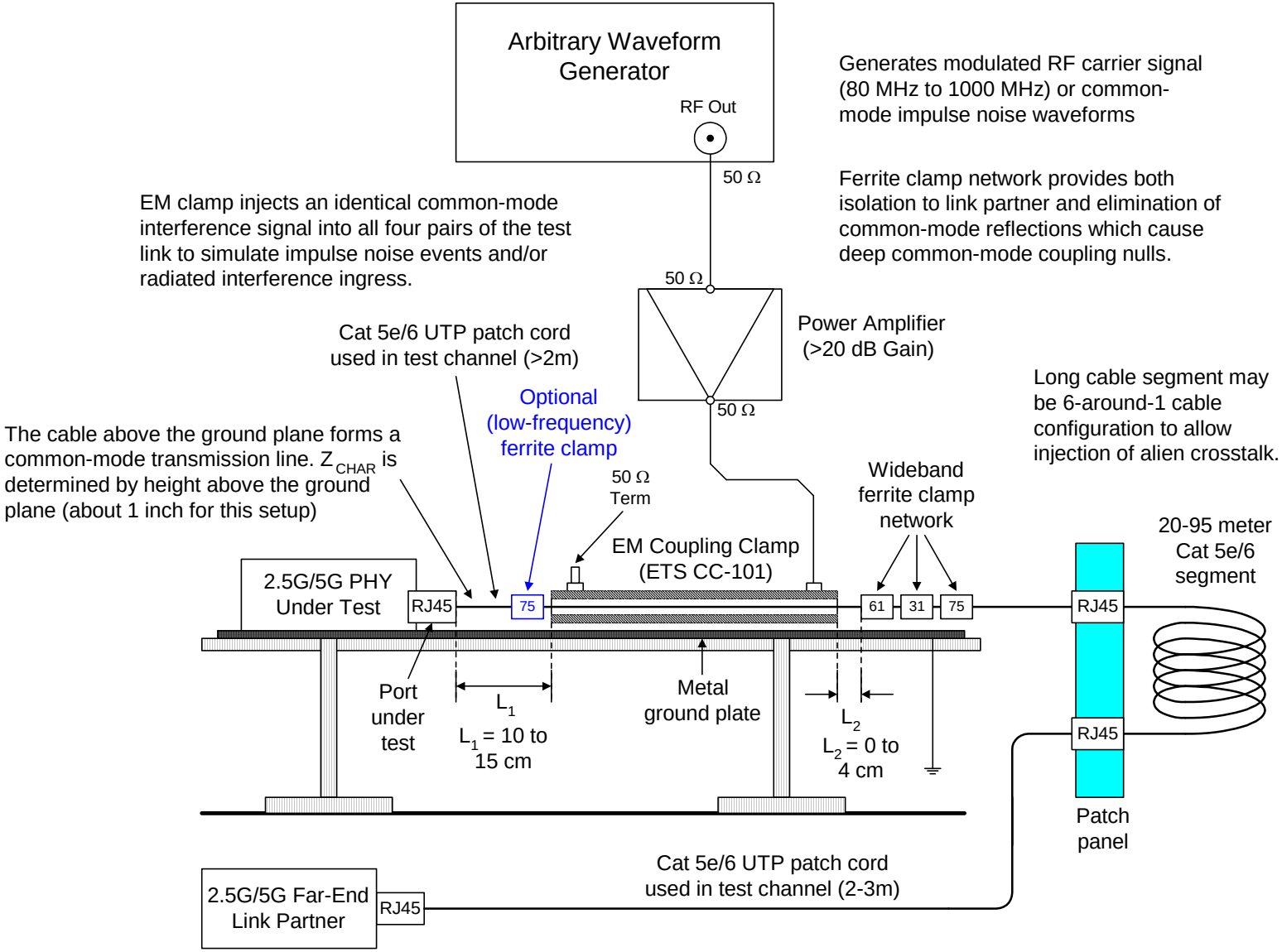
- EM coupling (Campbell) clamp specification defined in Annex 40B of 802.3
- Originally designed for common-mode interference signal injection up to 250 MHz into 1000Base-T channel
- Works as a coaxial transformer
- External ferrite suppression clamp network is required at far-end port for isolation of link partner and to suppress reflections at a (common-mode) impedance discontinuity



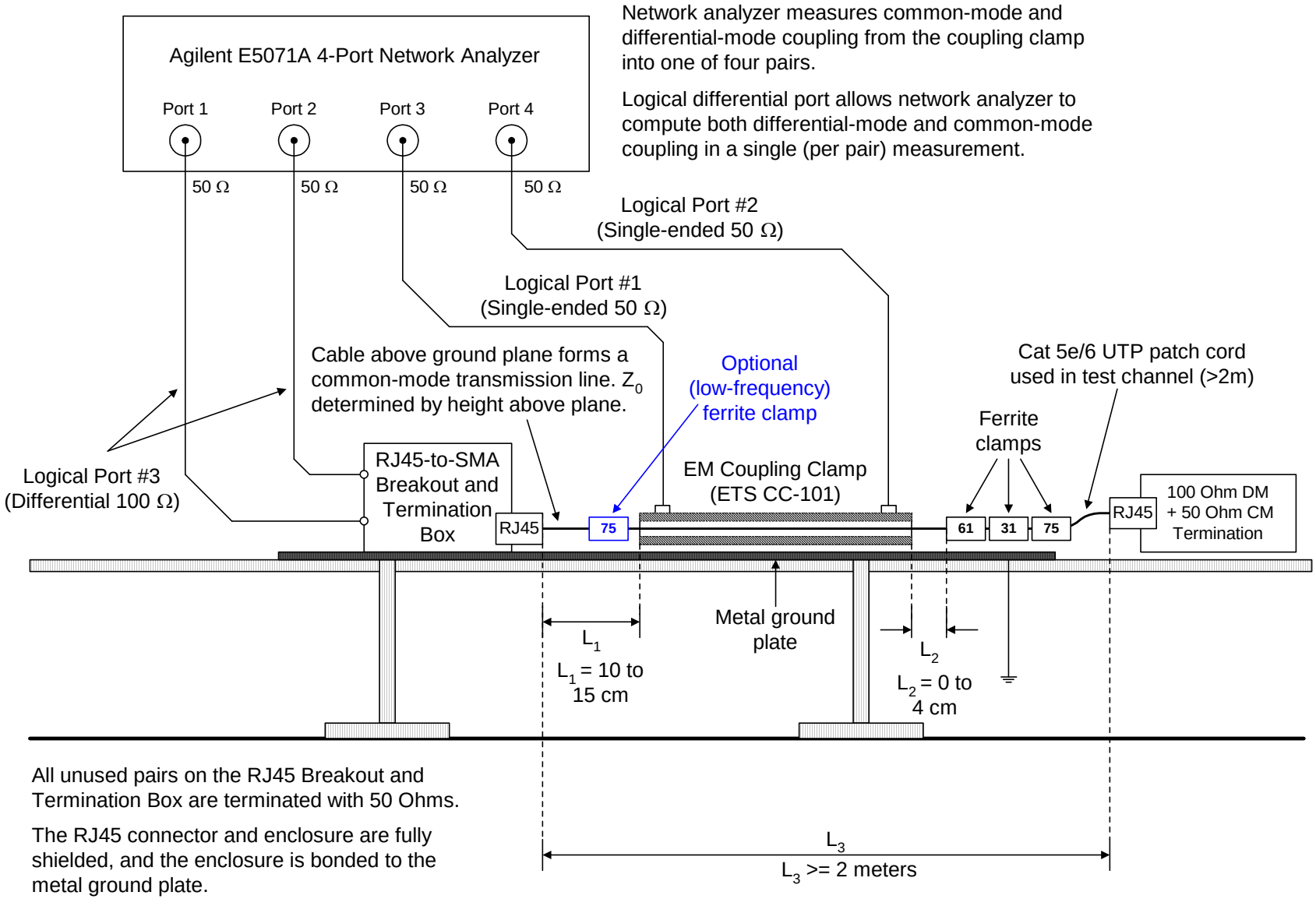
Properties of the EM Coupling (Campbell) Clamp

- Advantages
  - Produces effects similar to real-world interference; injects identical common-mode signal on all four pairs similar to exposure to an external EM field
  - Differential disturber signal created by channel imbalance; differential disturbers are NOT identical as would be the case in a real channel
  - Non-intrusive, does not disturb channel or degrade channel insertion loss and return loss
  - Coupling characteristics fairly consistent between units because of specified construction; coupling characteristics of EM absorbing clamps differ significantly between different manufacturers
- Disadvantages
  - Produced by only one supplier (ETS)
  - Requires relatively high power input stimulus because of large coupling losses
  - Internal resonance (reflections from internal impedance discontinuities) place test configuration restrictions for test signal frequencies above 250 MHz
  - External ferrite suppression clamp network must provide a minimum common-mode attenuation over a wide bandwidth

Example EM Clamp Setup for Impulse Noise (and Radiated Immunity) Testing



Test Setup to Measure EM (Campbell) Clamp Coupling



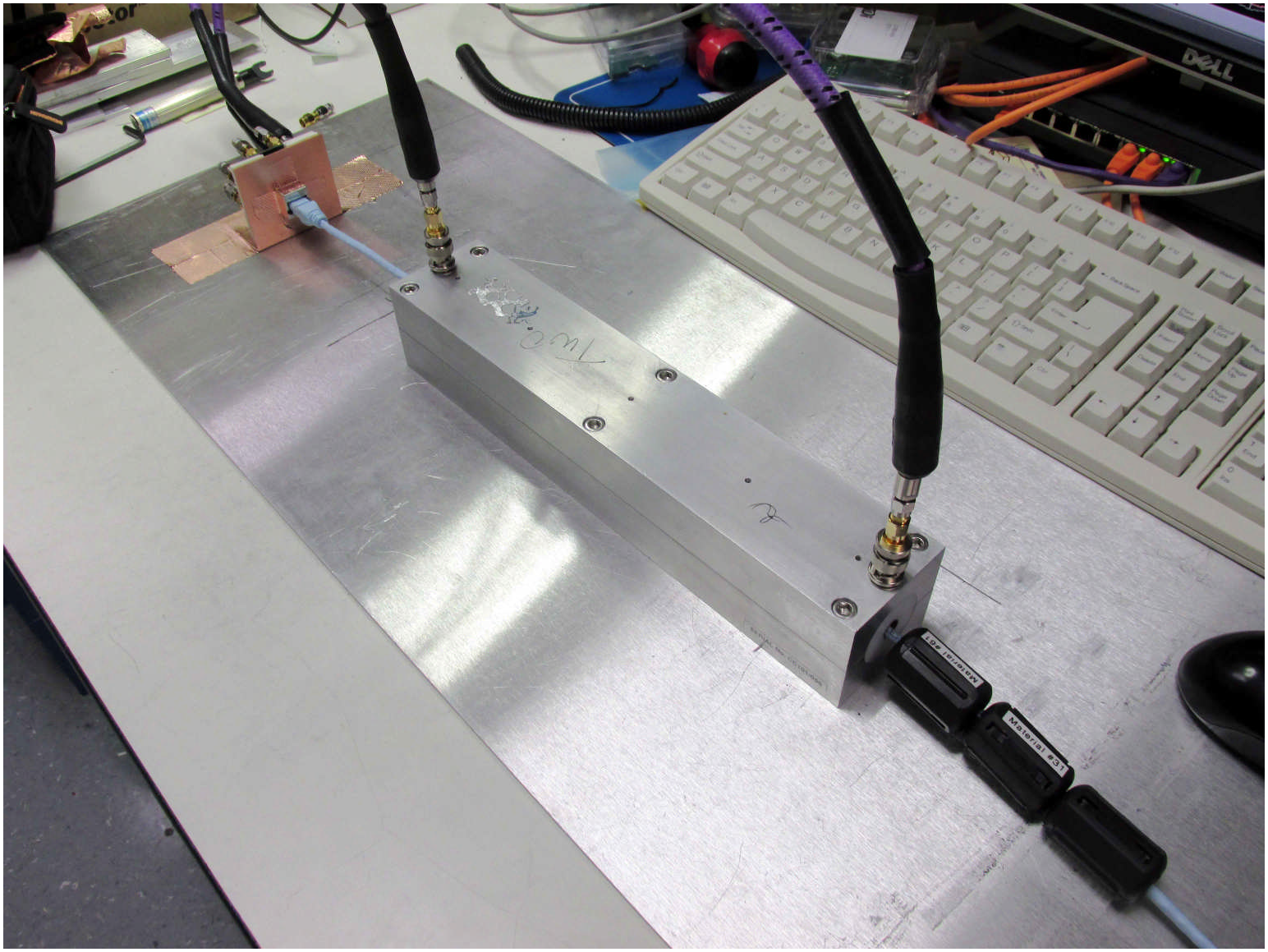
Network analyzer measures common-mode and differential-mode coupling from the coupling clamp into one of four pairs.

Logical differential port allows network analyzer to compute both differential-mode and common-mode coupling in a single (per pair) measurement.

All unused pairs on the RJ45 Breakout and Termination Box are terminated with 50 Ohms.

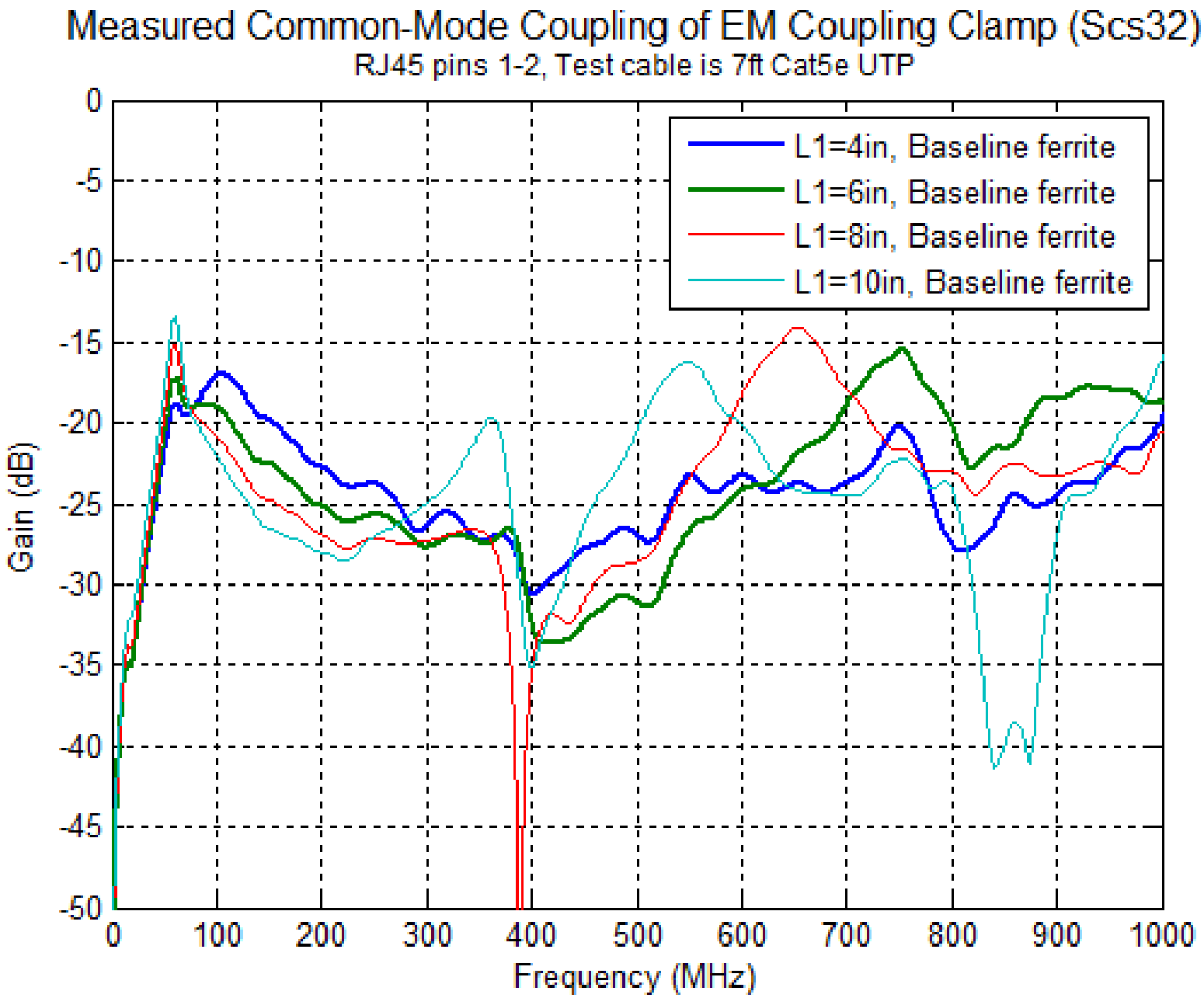
The RJ45 connector and enclosure are fully shielded, and the enclosure is bonded to the metal ground plate.

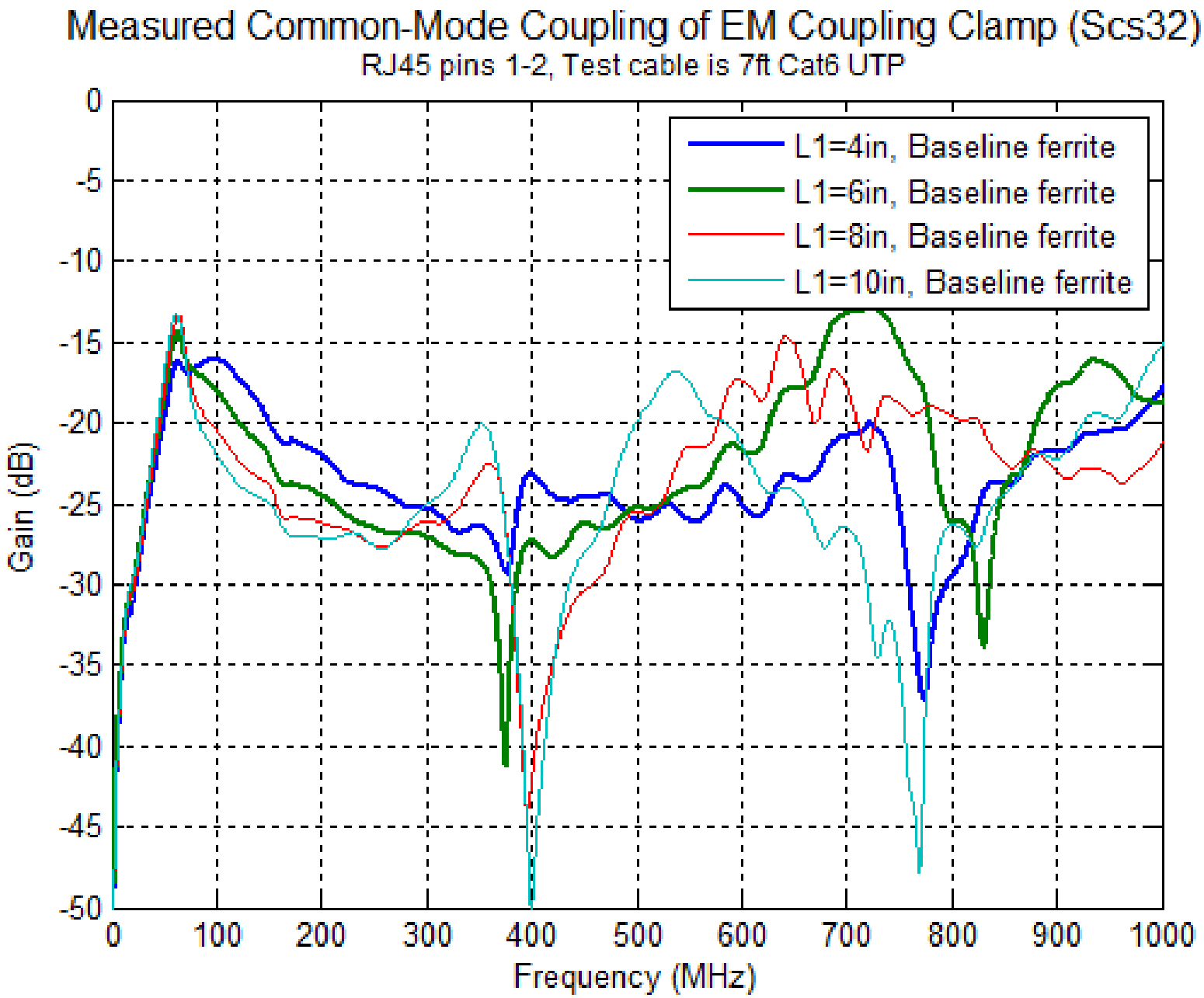
Test Setup to Measure EM (Campbell) Clamp Coupling

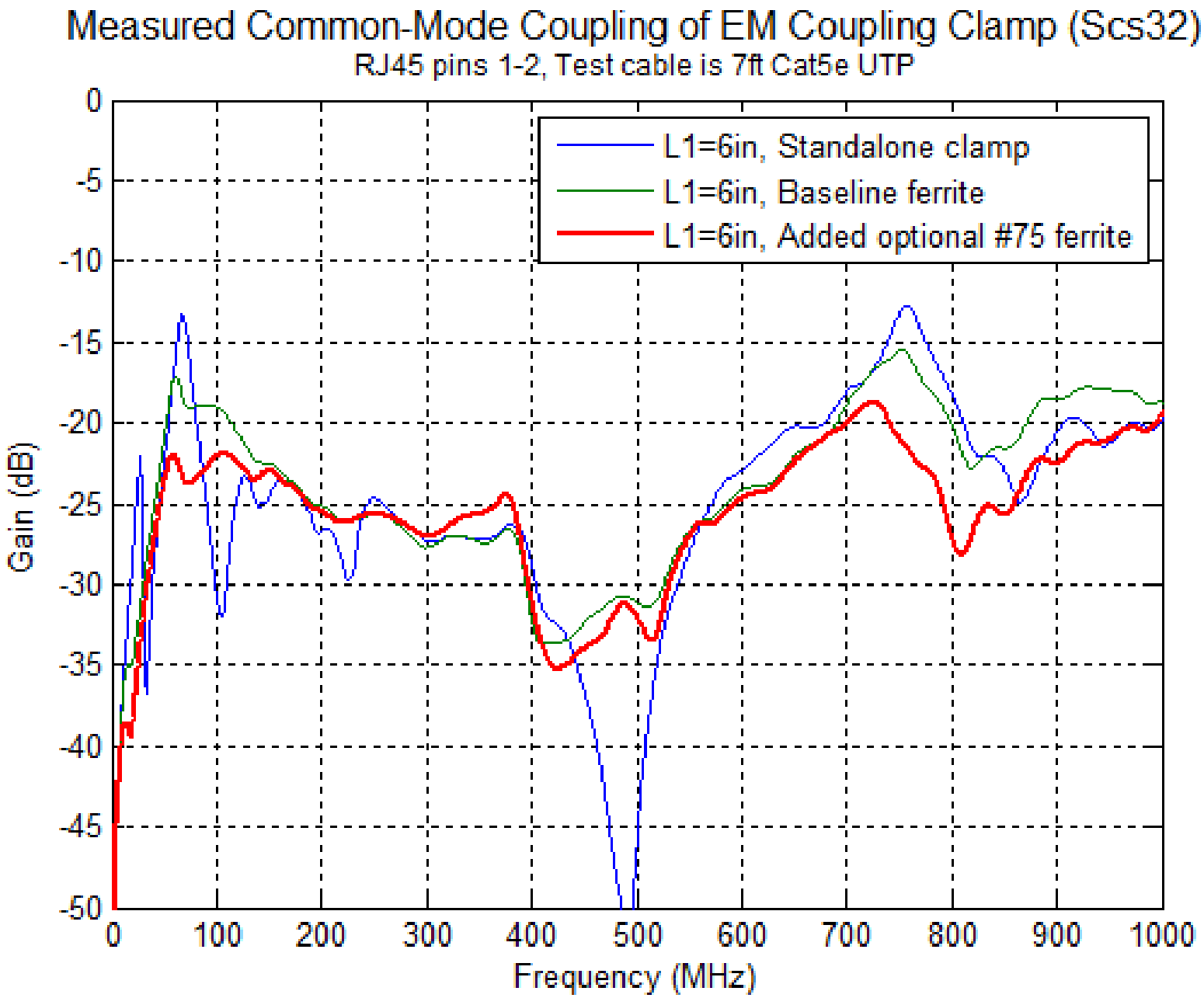


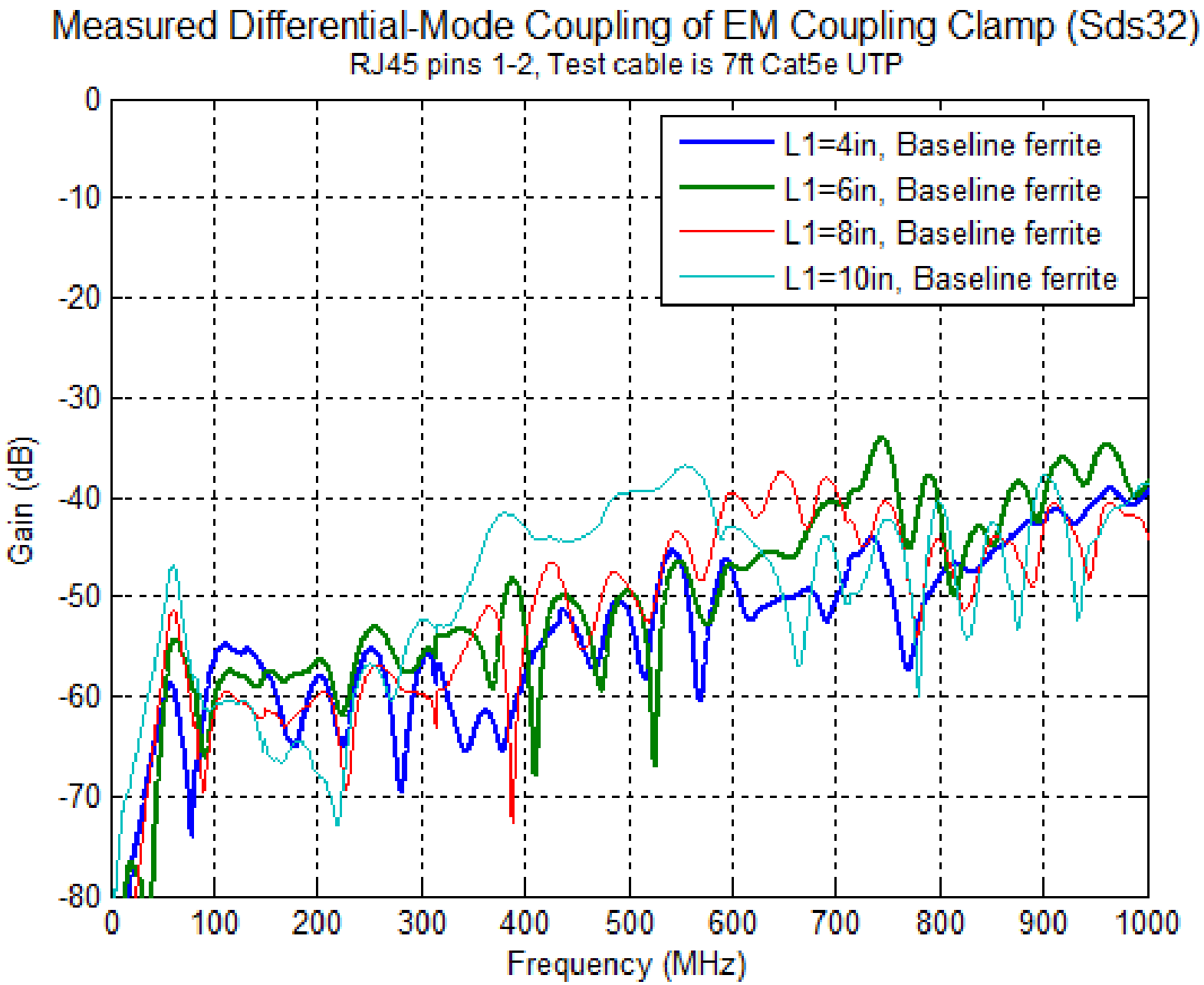
EM Coupling (Campbell) Clamp Measurement Results

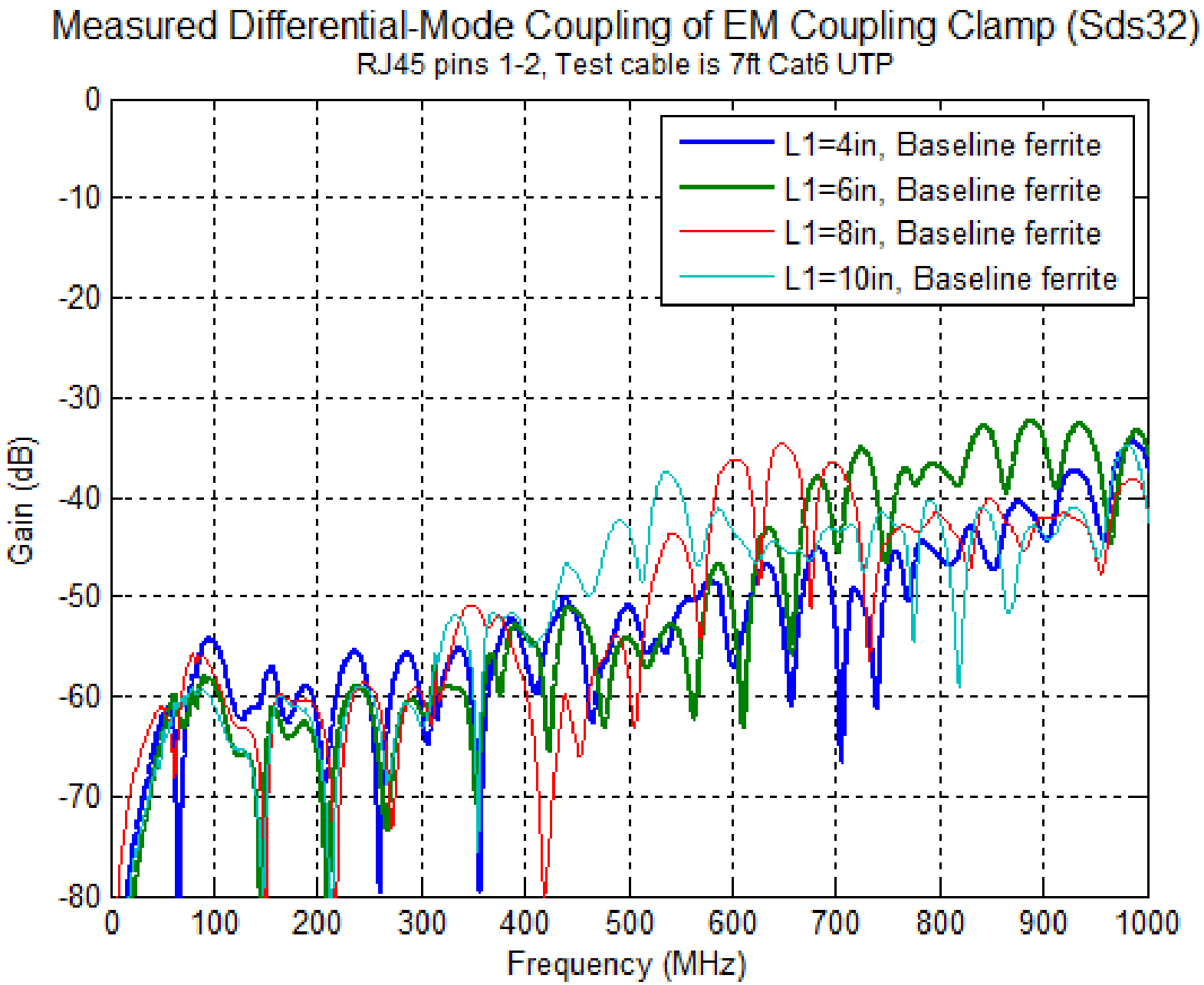
- Parameters measured
  - Common-mode coupling to test cable
  - Differential-mode coupling to test cable
  - Reflection at clamp input signal port
- Test cables
  - 7 ft Cat 5e patch cord with 100 Ohm differential/50 Ohm common-mode termination
  - 7 ft Cat 6 patch cord with 100 Ohm differential/50 Ohm common-mode termination
- Test configurations
  - Variation of distance between RJ45 port and clamp (L1) from 2 inches to 14 inches in 2 inch steps; plots only show results from L1 = 4, 6, 8, 10 inches
  - Measurement of configuration with L1=6 inches with various ferrite configurations
- Definitions
  - Baseline ferrite: Wideband ferrite clamp network at link partner port of clamp consisting three snap-on cable clamps of Fair-Rite material #61, #31, and #75
  - Standalone clamp: No snap-on ferrite clamps installed (demonstrates need for ferrite clamps)
  - Note material #61 is for high frequencies (above 100 MHz), material #75 is for low frequencies (below 20 MHz), and material #31 is for range from 10 MHz to 200 MHz

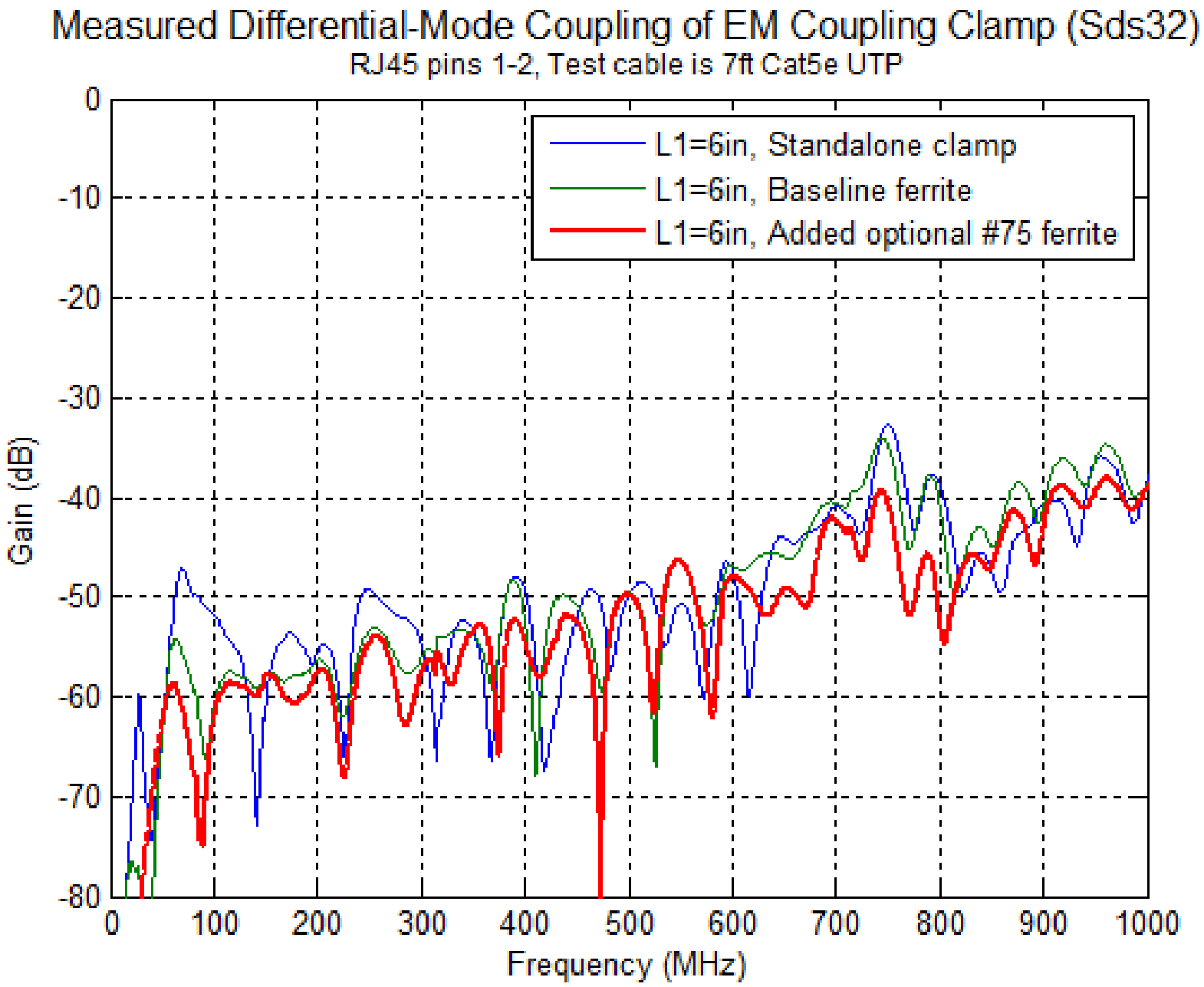

Measured Common-Mode Coupling of EM Coupling Clamp (Scs32)
RJ45 pins 1-2, Test cable is 7ft Cat5e UTP
L1=4in, Baseline ferrite
L1=6in, Baseline ferrite
L1=8in, Baseline ferrite
L1=10in, Baseline ferrite
Gain (dB)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
100
200
300
400
500
600
700
800
900
1000
Frequency (MHz)

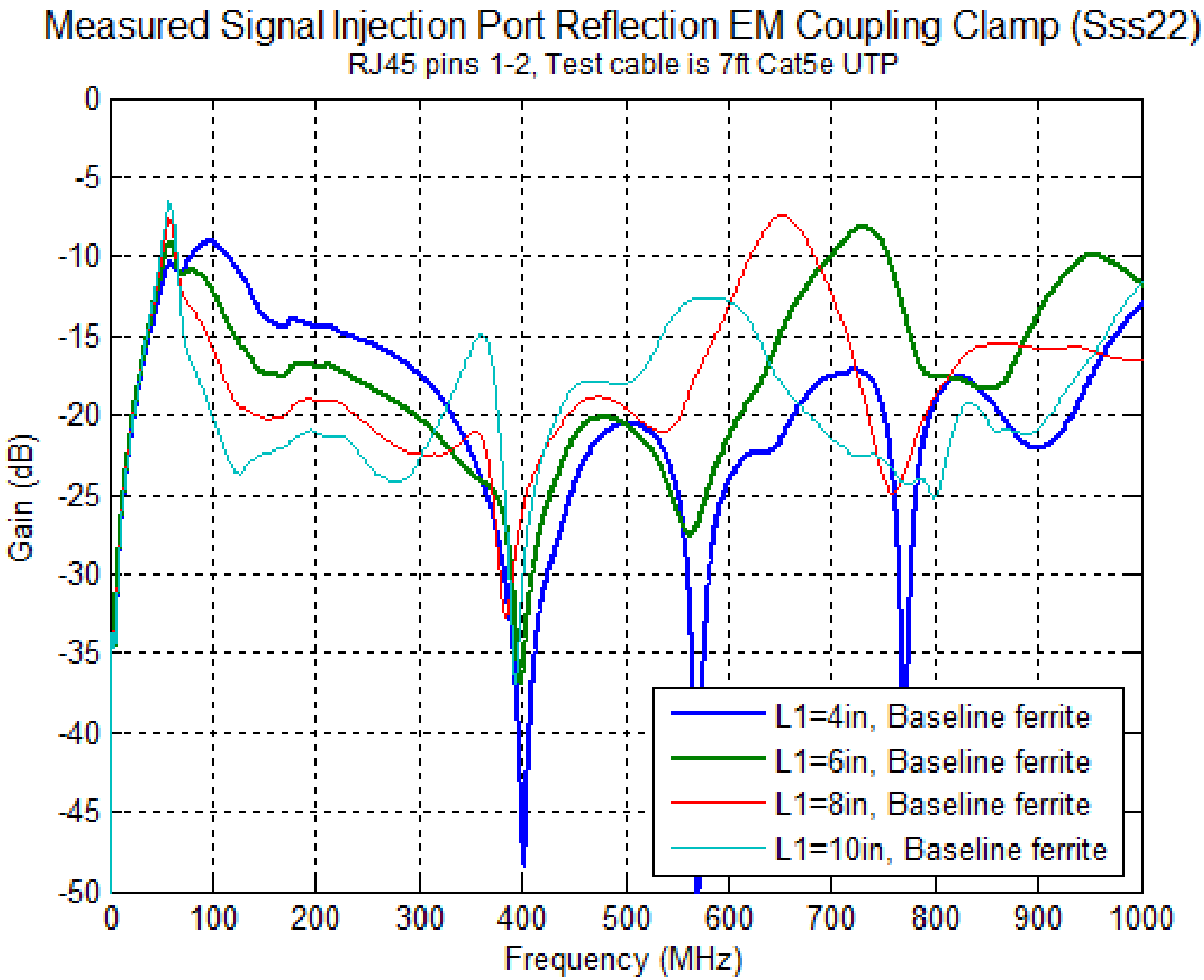

Measured Common-Mode Coupling of EM Coupling Clamp (Scs32)
RJ45 pins 1-2, Test cable is 7ft Cat6 UTP
L1=4in, Baseline ferrite
L1=6in, Baseline ferrite
L1=8in, Baseline ferrite
L1=10in, Baseline ferrite
Gain (dB)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
100
200
300
400
500
600
700
800
900
1000
Frequency (MHz)

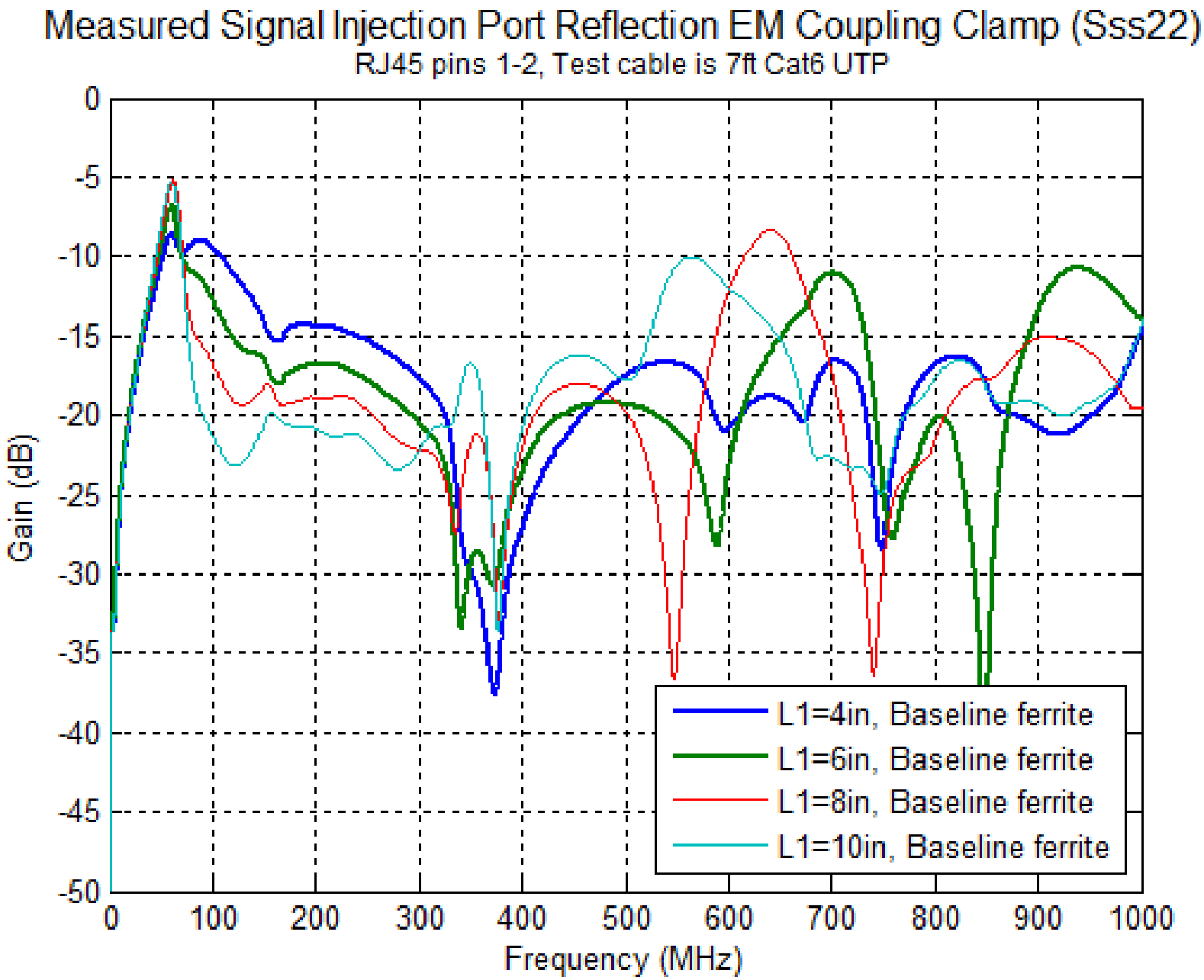

Measured Common-Mode Coupling of EM Coupling Clamp (Scs32)
RJ45 pins 1-2, Test cable is 7ft Cat5e UTP
L1=6in, Standalone clamp
L1=6in, Baseline ferrite
L1=6in, Added optional #75 ferrite
Gain (dB)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
100
200
300
400
500
600
700
800
900
1000
Frequency (MHz)

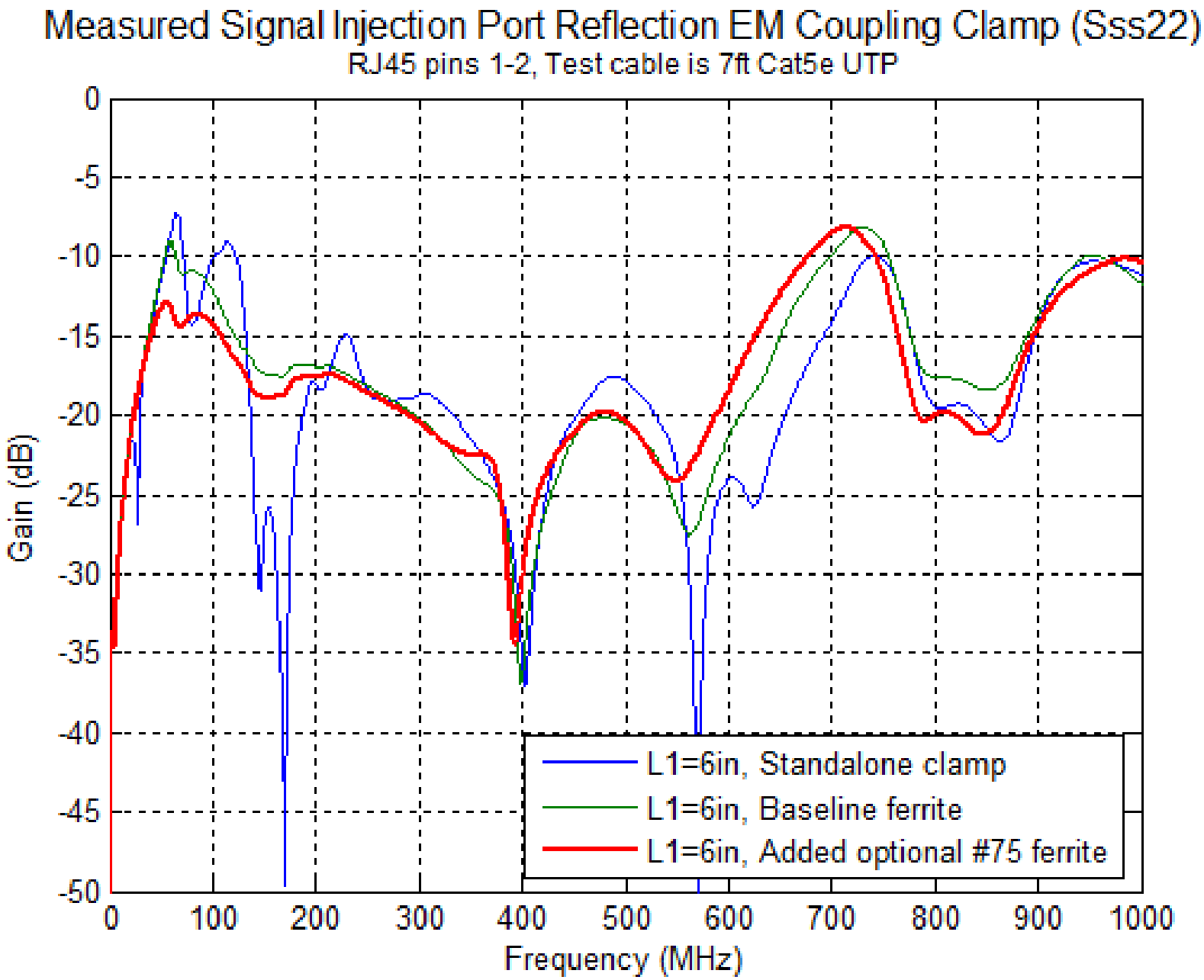

Measured Differential-Mode Coupling of EM Coupling Clamp (Sds32)
RJ45 pins 1-2, Test cable is 7ft Cat5e UTP
L1=4in, Baseline ferrite
L1=6in, Baseline ferrite
L1=8in, Baseline ferrite
L1=10in, Baseline ferrite
Gain (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
0
100
200
300
400
500
600
700
800
900
1000
Frequency (MHz)


Measured Differential-Mode Coupling of EM Coupling Clamp (Sds32)
RJ45 pins 1-2, Test cable is 7ft Cat6 UTP
L1=4in, Baseline ferrite
L1=6in, Baseline ferrite
L1=8in, Baseline ferrite
L1=10in, Baseline ferrite
Gain (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
0
100
200
300
400
500
600
700
800
900
1000
Frequency (MHz)


Measured Differential-Mode Coupling of EM Coupling Clamp (Sds32)
RJ45 pins 1-2, Test cable is 7ft Cat5e UTP
L1=6in, Standalone clamp
L1=6in, Baseline ferrite
L1=6in, Added optional #75 ferrite
Gain (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
0
100
200
300
400
500
600
700
800
900
1000
Frequency (MHz)


Measured Signal Injection Port Reflection EM Coupling Clamp (Sss22)
RJ45 pins 1-2, Test cable is 7ft Cat5e UTP
Gain (dB)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
100
200
300
400
500
600
700
800
900
1000
Frequency (MHz)
L1=4in, Baseline ferrite
L1=6in, Baseline ferrite
L1=8in, Baseline ferrite
L1=10in, Baseline ferrite


Measured Signal Injection Port Reflection EM Coupling Clamp (Sss22)
RJ45 pins 1-2, Test cable is 7ft Cat6 UTP
Gain (dB)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
100
200
300
400
500
600
700
800
900
1000
Frequency (MHz)
L1=4in, Baseline ferrite
L1=6in, Baseline ferrite
L1=8in, Baseline ferrite
L1=10in, Baseline ferrite


Measured Signal Injection Port Reflection EM Coupling Clamp (Sss22)
RJ45 pins 1-2, Test cable is 7ft Cat5e UTP
Gain (dB)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
100
200
300
400
500
600
700
800
900
1000
Frequency (MHz)
L1=6in, Standalone clamp
L1=6in, Baseline ferrite
L1=6in, Added optional #75 ferrite

Observations from EM Coupling Clamp Measurements

- Define “usable bandwidth” as a region where the common-mode coupling transfer function is reasonably flat and does not have any deep nulls
- The wideband ferrite clamp network at the link partner (far-end) port of the clamp is MANDATORY for all usable test configuration to provide isolation for auxiliary equipment and eliminate coupling nulls from common-mode reflections
- For usable bandwidth to 350 MHz with Cat 5e UTP and Cat 6 UTP, L1 (distance between clamp and DUT) can widely vary from 10 cm to 30 cm (4 inches to 12 inches)
- For usable bandwidth beyond 350 MHz up to 1GHz with Cat 5e UTP and Cat 6 UTP, L1 (distance between clamp and DUT) should be between 10 cm and 15 cm (4 and 6 inches), possibly less than 15 cm (6 inches) maximum for Cat 6 UTP
- The addition of 0.25 inch thick small metal slabs between the clamp and DUT (RJ45 test port) to reduce the height of the test cable above the ground plane (reduce common-mode impedance) slightly improved
- Added low-frequency ferrite clamp (material #75) improves clamp input port return loss and flattens common-mode coupling curve, but reduces low frequency common-mode coupling
- The low frequency common-mode coupling loss is very high; this may be problem for EFT waveform impulse noise testing

- **The test setup diagram shown in slide #5 may be useful as a starting point in defining a test setup for impulse noise testing in the standard**

Next Steps and Discussion Points

- Measure impedance of ferrite clamp network to provide a proper standard specification
- Test clamp coupling with screened and shielded cable

- Should an RJ45 junction be added 2 to 3 meters from the DUT port on the test cable configuration?
  - Realistic installation practice; simulates patch cord run from desk/wall RJ45 jack to network equipment
  - Increases common-mode to differential conversion
- Should we consider alternative test setups with either an EM absorbing clamp or a differential injection test fixture?