Test Report for
Qualification Testing

Performed on an
Electrical Protective Technology Device

Issue Date: March 12, 2018

Prepared for: **Digilant**
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SIGNATURES

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Revision Log

Revision #	Description	Date
0	Original Copy	8/16/2017
1	Integrated Leveler Editorial Comments	9/25/2017
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1.0 ADMINISTRATIVE DATA

1.1 Purpose of Tests

The primary purpose of this test program was to determine if the Equipment Under Test (EUT), a Bantam surge protection device (SPD), which uses a simple and non-traditional SPD design composed of only MOVs and inductors, provided any additional features such as power factor correction, low or high frequency noise suppression of bi-directional filtering. The primary objective was to perform investigative testing on this Electrical Protective Technology Device. The Bantam SPD device, herein referred to as the test item or EUT, was provided by Digilant.

1.2 Description of Test Item

The test item is a single phase 115VAC 15Amp power outlet surge protection device.

1.3 Manufacturer

Digilant
4767 E. Wesley Drive
Anaheim, CA 92807

1.4 References

- Digilant Purchase Order No. 1009371
- NTS Huntsville's Opportunity No. OP0180915
- ANSI/NCSL Z540.3:2007, "Calibration Laboratories and Measuring and Test Equipment, General Requirements"
- Leveler Surge Protection Device (SPD) Test Plan dated 09/04/2015, Initial Release
- DI-EMCS-80200C, "Data Item Description for an Electromagnetic Interference Test Report (EMITR)"
- ISO 10012:2003, "Quality Assurance Requirements for Measuring Equipment"

1.4 References (Continued)

- ISO/IEC 17025:2005, "General Requirements for the Competence of Test and Calibration Laboratories"

1.5 Quantity of Items Tested

Table 1-1 Test Item

Quantity	Test Item Description	Part Number	Serial Number
1	Single phase AC power outlet surge protection device	550-PP4004A	1107-5-0027

1.6 Security Classification

Unclassified

1.7 Tests Conducted By

National Technical Systems
Huntsville Facility
7800 Highway 20 West
Huntsville, Alabama 35806

1.8 Standard Test Conditions

Unless otherwise specified herein, all tests was performed at the following standard ambient conditions:

- Temperature: 60ºF ± 20ºF (15ºC ± 11ºC)
- Relative Humidity: 20% to 80%
- Atmospheric Pressure: 30 ± 2 inches-Hg (76 ± 5cm – Hg)

1.9 Test Equipment and Instrumentation

All instrumentation, measuring, and test equipment used in the performance of this test program was calibrated in accordance with NTS Plano Quality Assurance Program which complies with the requirements of ISO/IEC 17025:2005. Standards used in performing all calibrations are traceable to the National Institute of Standards and Technology (NIST) by report number and date. When no national standards exist, the standards are traceable to international standards or the basis for calibration is otherwise documented.

1.10 Test Tolerances

Test tolerances are used to maintain reasonable controls for obtaining consistent measurements. This tolerance should not be mistaken for measurement uncertainty.

Unless otherwise specified herein, the following tolerances were used:

- Time: ± 5%
- Temperature: ± 3.6°F (± 2°C)
- Relative Humidity: ± 5%
- Distance: ± 5%
- Frequency: ± 2%
- Amplitude, Measurement Receiver: ± 2dB
- Total Amplitude Measurement System: ± 3dB
  (Includes receivers, cabling, and transducer components)

1.11 Quality Assurance

All work performed on this program was in accordance with NTS Corporate Quality Policy Manual, Current Revision.

1.12 Source Inspection

NTS Plano QA

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2.0 TEST SUMMARY

The test program consisted of the tests listed in Table 2-1. Test performed in Sections 5 and 6

Table 2-1 Test Summary

Section	Test ID	Test Description	Requirements
3.5	Receipt Inspection	An inspection was performed upon receipt of the EUT at NTS Plano.	The EUT was checked to ensure that it was as described. Additionally, the EUT was visually inspected for any physical damage.
4.0	LCR	LCR Measurement	To measure the LCR characteristics of the EUT
5.0	Insertion Loss	Insertion Loss 60 Hz to 30 Mz	To measure Common Mode and Differential Mode insertion loss of the EUT
6.0	Current Harmonics	Current Harmonics suppression 30 Hz – 10 kHz	To measure the EUT performance to suprress current harmonic distortion

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3.0 EUT INFORMATION

3.1 EUT Description

The test item is a single phase AC power outlet surge protection device, as indicated in Figure 3-1.

Figure 3-1 Electrical Protective Technology Device

3.2 EUT Support Equipment

No support equipment was required for this evaluation

3.3 EUT Test Setup

The EUT was configured in accordance with Leveler Surge Protection Device (SPD) Test Plan dated 09/04/2015, Initial Release, and/or as modified by the customer's instructions.

1. The EUT installation and operation was verified prior to start of testing.

2. The EUT physical layout was performed by NTS Plano personnel in accordance with the Leveler Surge Protection Device (SPD) Factory Acceptance Test Plan.

3.4 Receipt Inspection

On receipt of the EUT, NTS Plano personnel performed a visual receiving inspection for any damage that may have occurred during shipment. The results were recorded on the Receiving Inspection Form. This form was used to record part number(s), serial number(s), and description(s) of the EUT, quantity received, the date and documentation of any apparent physical damage that may have occurred during shipment of the EUT.

3.5 Test Setup

Test setup was assembled in accordance with Leveler Surge Protection Device (SPD) Factory Acceptance Test Plan as applicable to the associated test being performed.

3.6 Test Methods

All tests were conducted in accordance with the test methods specified per Leveler Surge Protection Device (SPD) factory acceptance test plan except where otherwise specified by the details as indicated from the customer.

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4.0 LCR MEASUREMENTS

4.1 Purpose

The purpose of this test was to characterize the Inductance (L), Capacitance ©, and Resistive (R) elements of the Leveler SPD.

4.2 Requirements

The requirement of this test was to measure LCR Characteristics of Line, Neutral, and Ground conductors commonly as well as differentially.

4.3 Test Equipment

The test equipment required for this test is listed in Table 4-1. Substitution of equipment with equivalent capability may be utilized in the performance of the test. Actual equipment used is listed in the Instrumentation Equipment Sheet.

Table 4-1 LCR Measurement Test Equipment

Item Description	Frequency Range	Manufacturer/Model No.	Quantity
LCR Meter	DC -100 kHz	Agilent U1732C MY53080030	1

4.4 Calibration (Measurement System Check)

1. The self-calibration routine was performed on the LCR meter prior to measurements.

4.5 Test Method

1. The equipment for testing was set up as shown in Figure 4-1

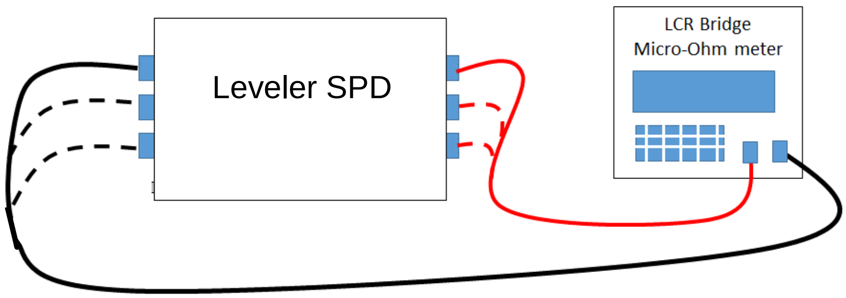

Figure 4-1 LCR Measurement Setup

Resistance Measurements

- Connect the meter across each line (End to End), to determine the Resistance of each line at a frequency of 1 kHz.
- Connect the meter between Line and Neutral to determine the Resistance of each line at a frequency of 1 kHz.
- Connect the meter between Line and Ground to determine the Resistance of each line at a frequency of 1 kHz.
- Connect the meter between Neutral and Ground to determine the Resistance of each line at a frequency of 1 kHz.

Capacitance Measurements

- Connect the meter across each line (End to End), to determine the Capacitance of each line at a frequency of 1 kHz.
- Connect the meter between Line and Neutral to determine the Capacitance of each line at a frequency of 1 kHz.
- Connect the meter between Line and Ground to determine the Capacitance of each line at a frequency of 1 kHz.
- Connect the meter between Neutral and Ground to determine the Capacitance of each line at a frequency of 1 kHz.

Inductance Measurements

- Connect the meter across each line (End to End), to determine the Inductance of each line at a frequency of 1 kHz.
- Connect the meter between Line and Neutral to determine the Inductance of each line at a frequency of 1 kHz.
- Connect the meter between Line and Ground to determine the Inductance of each line at a frequency of 1 kHz.
- Connect the meter between Neutral and Ground to determine the Inductance of each line at a frequency of 1 kHz.

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4.6 Test Results

The EUT test results were found compliant with the customer's expectations.

The test results contain the following information:

- Data Sheet
- Photographs

4.7 Analysis

The Series Inductance was found to be approximately 250 µH per line.
The Series Resistance was found to be approximately 0.35 ohms per line.
The Series capacitance was found to be between 1.94 and 1.99 µF on each line. This is attributed to the inter-winding capacitance of the series inductor.
The common mode capacitance was found to be 5.5 nF on each line. This can be attributed to the metal oxide varistor (MOV) surge protective element installed on each line.
The Common mode resistance was found to be greater than 1 Mohm on each line.

4.8 LCR Measurement Photographs

Figure 4-2 LCR Measurement Setup

4.9 LCR Measurement Datasheet

Table 4-2 LCR Measurements

Measurement configuration	DC Resistance (Ω)	Inductance (L) at 1 kHz	Capacitance (C)
Line	0.35 Ω	249 µH	1.94 µF
Neutral	0.44 Ω	245 µH	1.99 µF
Ground	0.33 Ω	240 µH	1.95 µF
Line to Ground	>1M Ω	N/A	5.5 nF
Neutral to Ground	>1M Ω	N/A	5.5 nF
Line to Neutral	>1M Ω	N/A	5.5 nF

5.0 INSERTION LOSS

5.1 Purpose

The purpose of this test was to measure the common and differential mode Insertion Loss characteristics of the leveler device from 60 Hz to 30 MHz.

5.2 Requirements

1. Set up the equipment as shown in Figure 5-1. For the common mode matched load test. The individual leads of the leveler SPD shall be terminated together and attached to the high side of the signal generator as well as the spectrum analyzer. The return connection for the signal generator and spectrum analyzer shall be bonded to the conductive ground plane.
2. Allow warm up of any equipment to be used to ensure that stability has been reached. Additionally, the minimum warm-up time should be the maximum warm-up time of any given instrument used in the test unless otherwise specified.
3. Program the signal generator and spectrum analyzer to 60 Hz. Set the signal generator amplitude to 5 dBm. Set spectrum analyzer to measure in dBm. Set the measurement resolution bandwidth to 10 Hz, and frequency span to 1 Hz.
4. Step through the measurement range at a rate of 20 frequencies per decade.
5. Adjust both signal generator and spectrum analyzer settings at each test frequency.
6. Record the signal amplitude measured at each frequency, and plot the data along a linear over log graph.
7. Set up the equipment as shown in Figure 5-2. For the differential mode matched load test. The individual leads of the leveler SPD shall be connected to the high side and return side of the signal generator as well as the spectrum analyzer.
8. Repeat steps 2 through 6.
9. Place the Leveler SPD in series with the test circuit. Plug the leveler SPD power cord into the test adapter, and plug the test adapter into the leveler SPD receptacle as depicted in Figure 5-3.
10. Repeat steps 2 through 6.
11. Add the calibrated insertion loss data to the test data. Subtract from the test data to yield the filters corrected common mode insertion loss and plot the data along a linear over log graph.

12. Place the Leveler SPD in series with the test circuit. Plug the leveler SPD power cord into the test adapter, and plug the test adapter into the leveler SPD receptacle as depicted in Figure 5-4.
13. The individual leads of the leveler SPD shall be terminated together and attached to the high side of the signal generator as well as the spectrum analyzer. The return connection for the signal generator and spectrum analyzer shall be bonded to the conductive ground plane.
14. Repeat steps 2 through 7.
15. Add the calibrated insertion loss data to the test data. Subtract from the test data to yield the filters corrected common mode insertion loss and plot the data along a linear over log graph.

Table 5-1 High Frequency Insertion Loss Test Equipment

Item Description	Frequency Range	Manufacturer/Model No.	Quantity
Function Generator	DC - 100 kHz	HP 8116A	1
Spectrum Analyzer	3 Hz – 26.5 GHz	Agilent/E4440A	1
Signal Generator	10 kHz – 1.35 GHz	Marconi 2030	1

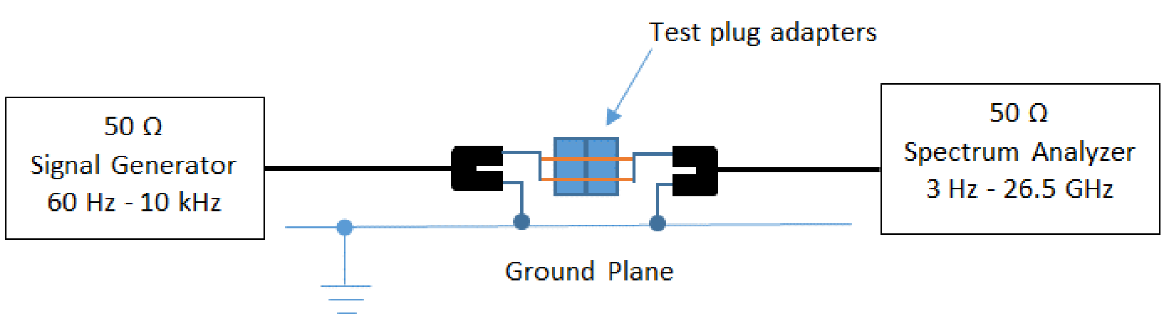

Figure 5-1 Common Mode Calibration Setup

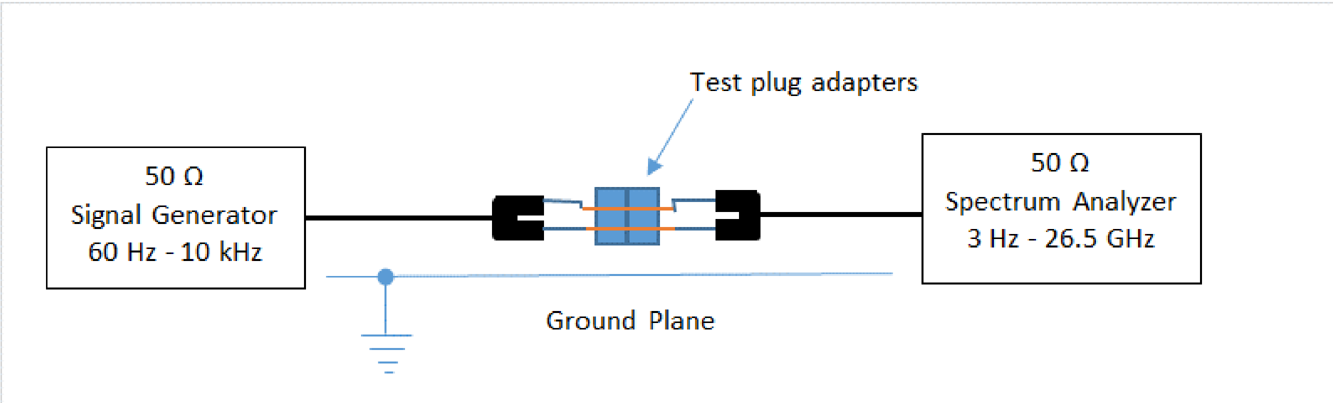

Figure 5-2 Differential Mode Calibration Setup

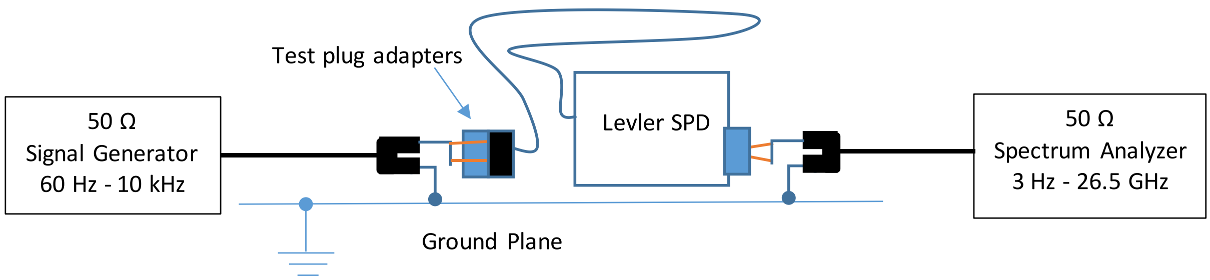

Figure 5-3 Common Mode Test Setup

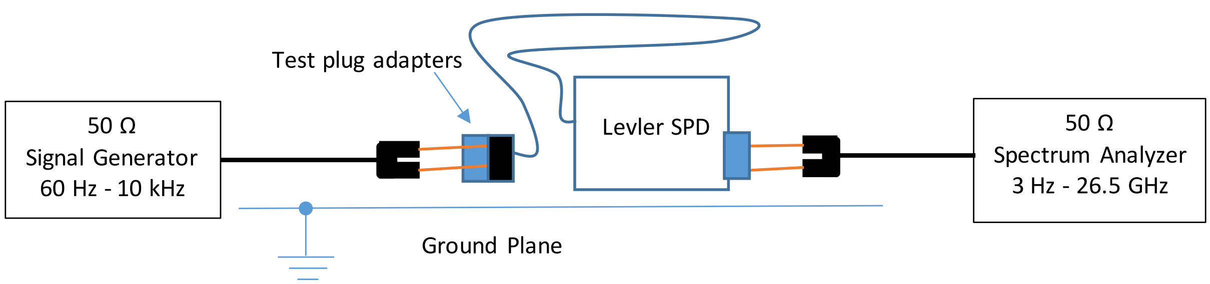

Figure 5-4 Differential Mode Test Setup

5.3 Test Results

The EUT test results were found consistent and as expected by Leveler engineering.

The test results contain the following information:

- Photograph(s)
- Data Plot(s)

5.4 Analysis

The common mode insertion loss measurement revealed a broad resonance at 1 MHz providing approximately 18 dB of insertion loss, with no attenuating effects observed below 10 kHz.
The differential mode insertion Loss measurements revealed a very similar characteristic response at 1 MHz, as well as continued RF attenuation averaging approximately 25 dB to 30 MHz.

5.5 Insertion Loss Photographs

Figure 5-5 Common Mode Insertion Loss Calibration Setup

Figure 5-6 Common Mode Insertion Loss Calibration Setup (Close up)

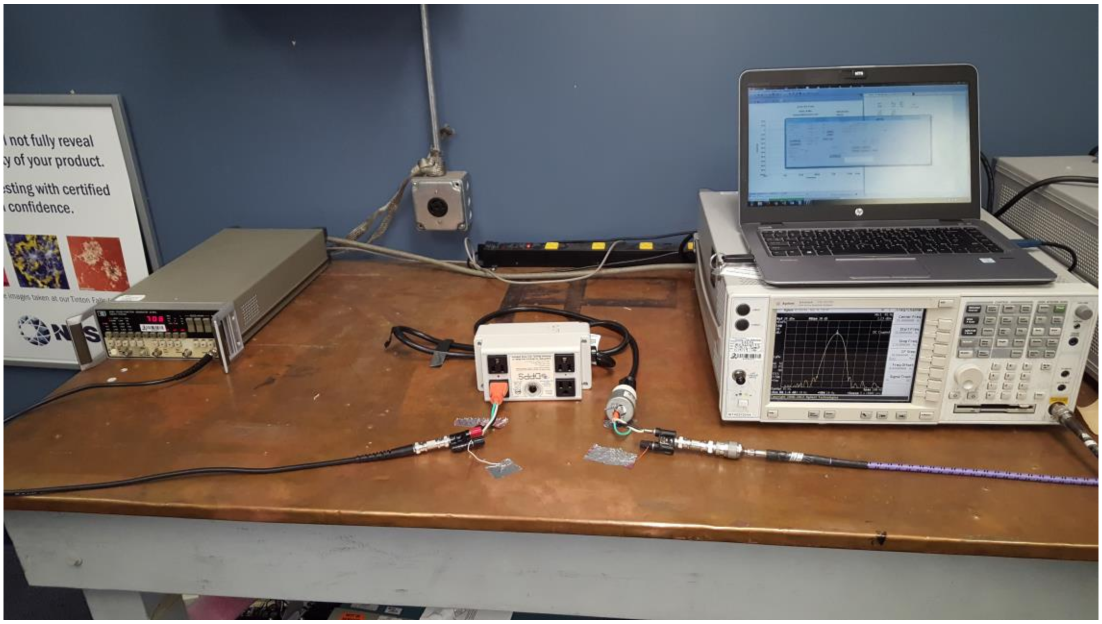

Figure 5-7 Common Mode Insertion Loss Test Setup

Figure 5-8 Common Mode Insertion Loss Test Setup (Close Up)

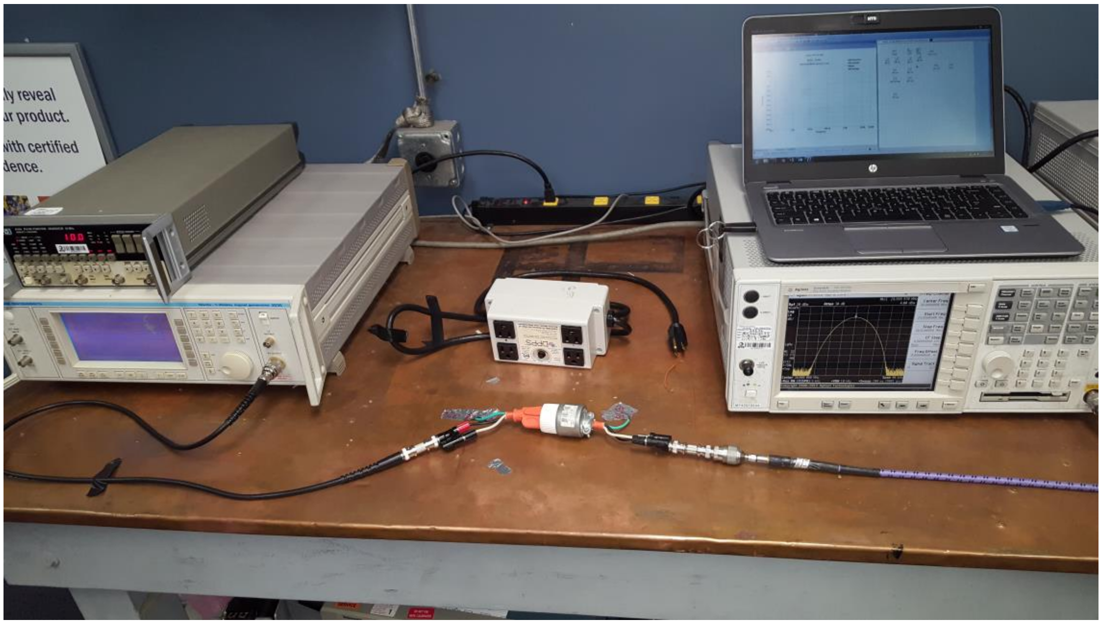

Figure 5-9 Differential Mode Insertion Loss Calibration Setup

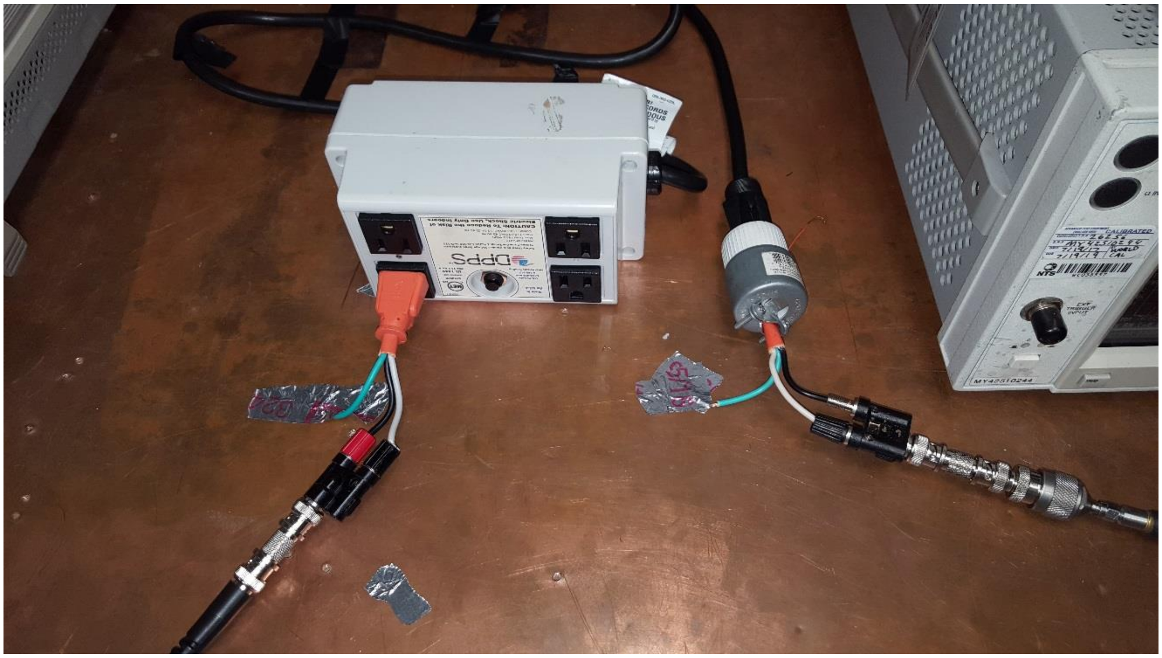

Figure 5-10 Differential Mode Insertion Loss Calibration Setup (Close up)

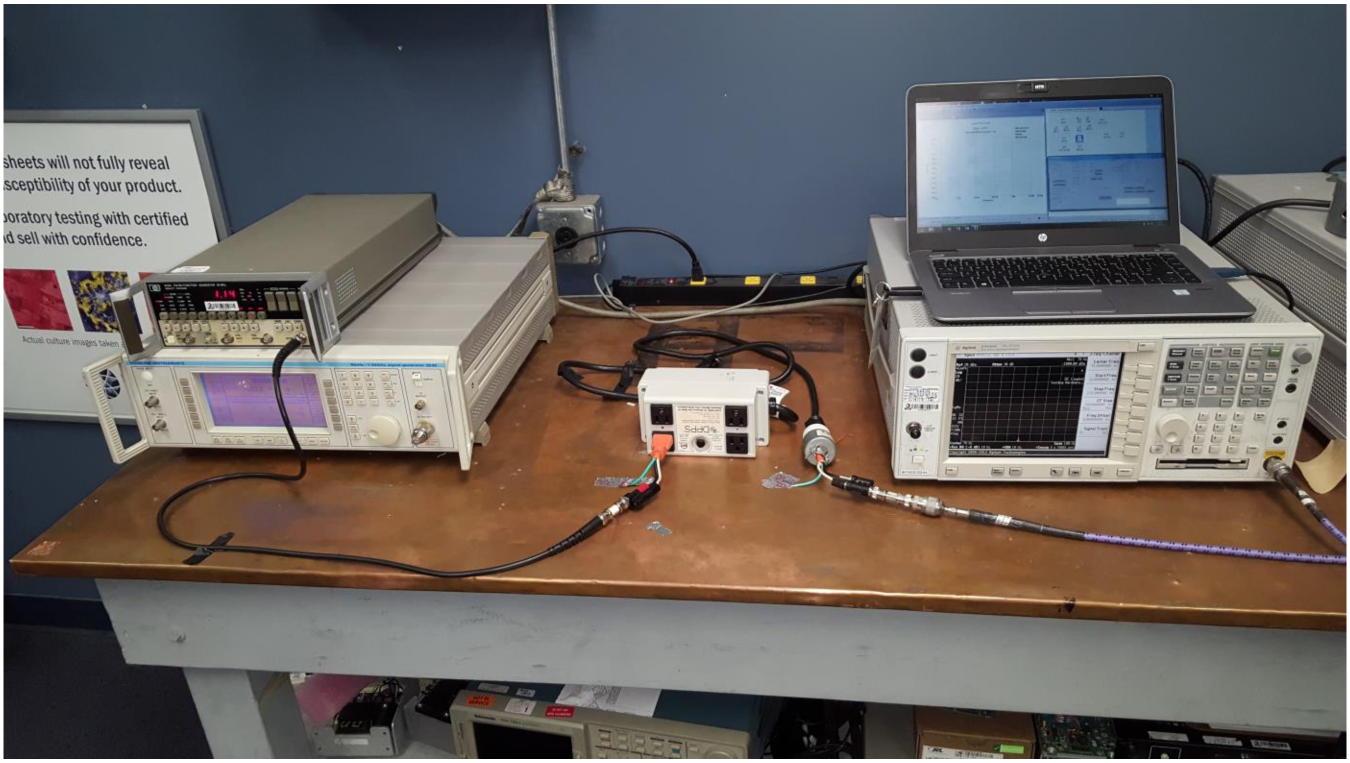

Figure 5-11 Differential Mode Insertion Loss Test Setup

5.6 Insertion Loss Test Data

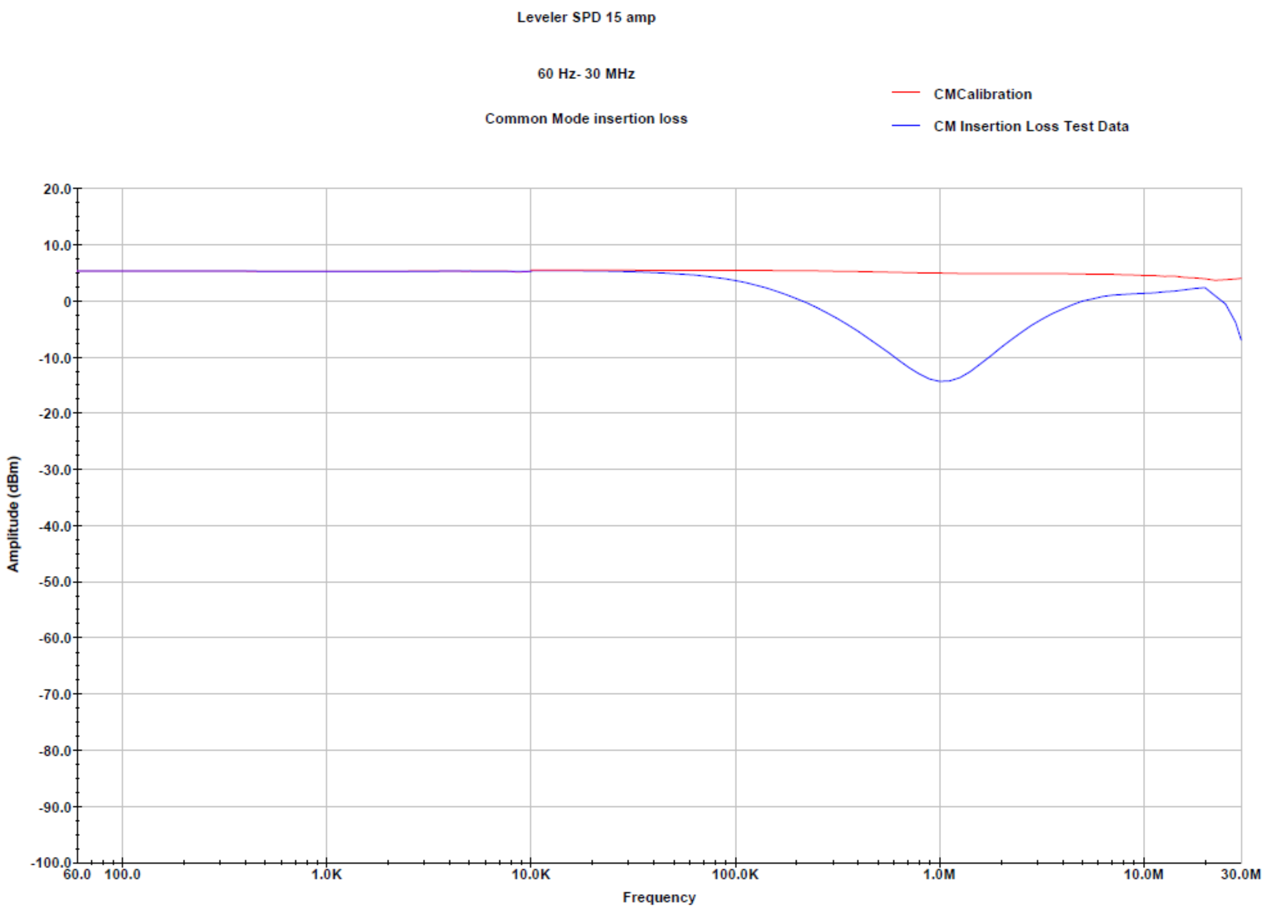

Figure 5-12 Common Mode Insertion Loss Calibration versus Test Data

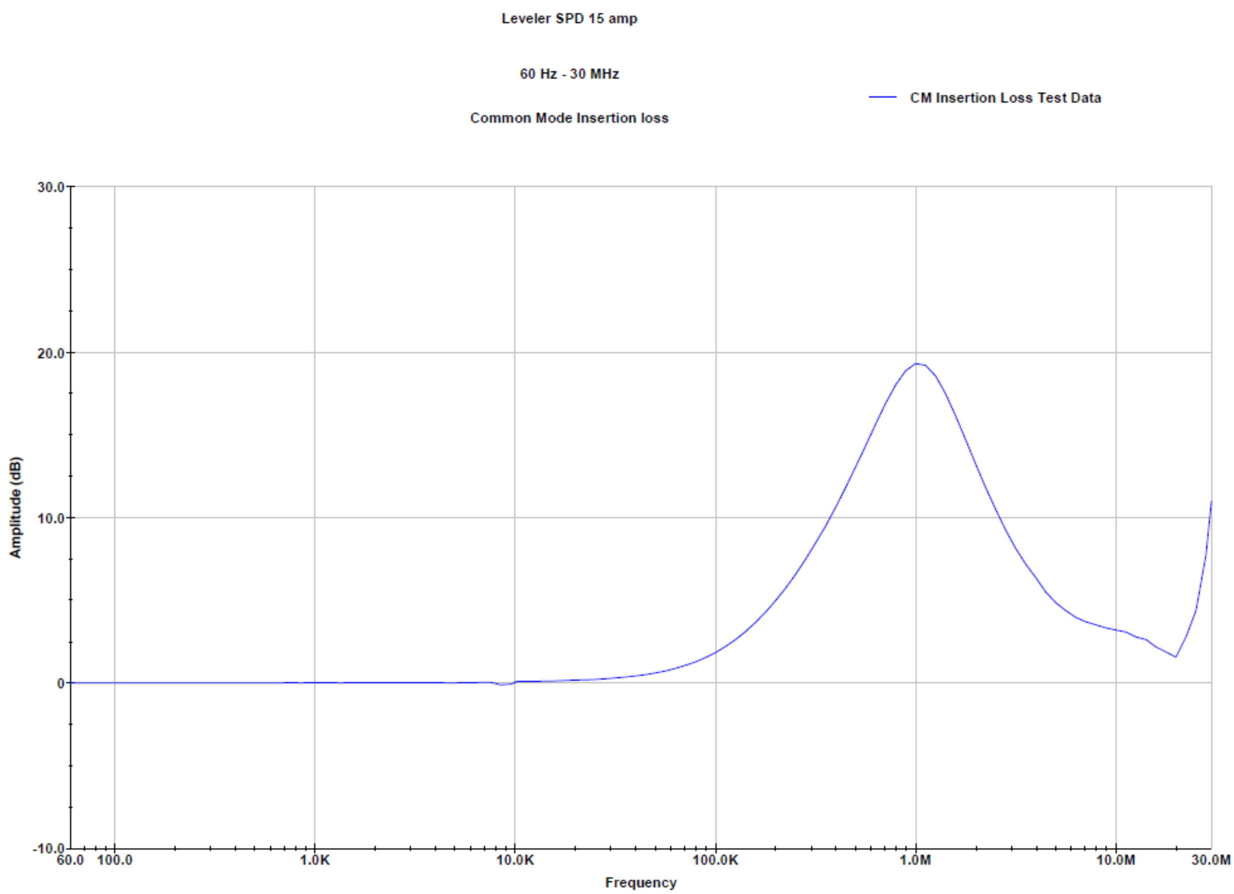

Figure 5-13 Common Mode Insertion Test Data

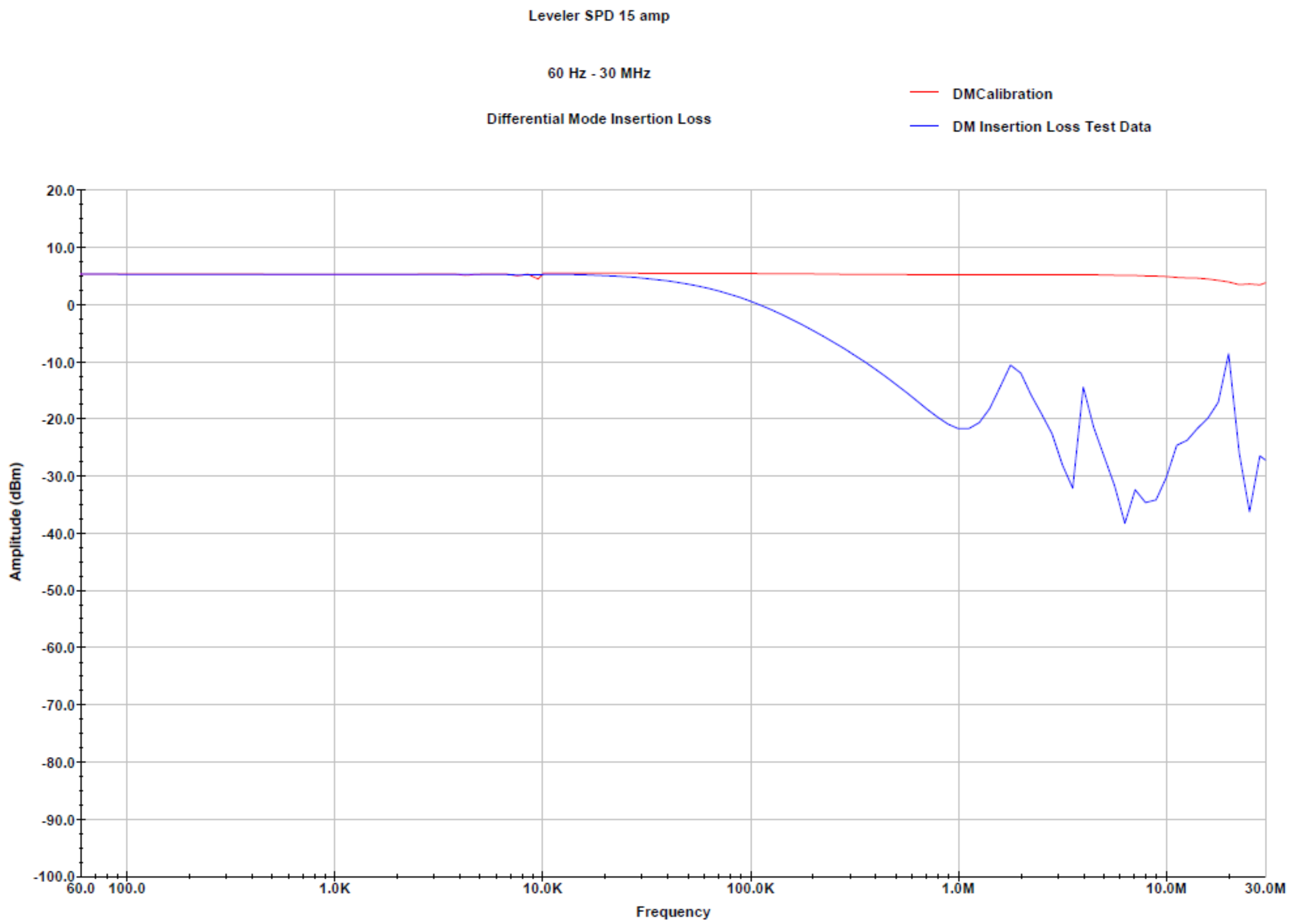

Figure 5-14 Differential Mode Insertion Loss Calibration versus Test Data

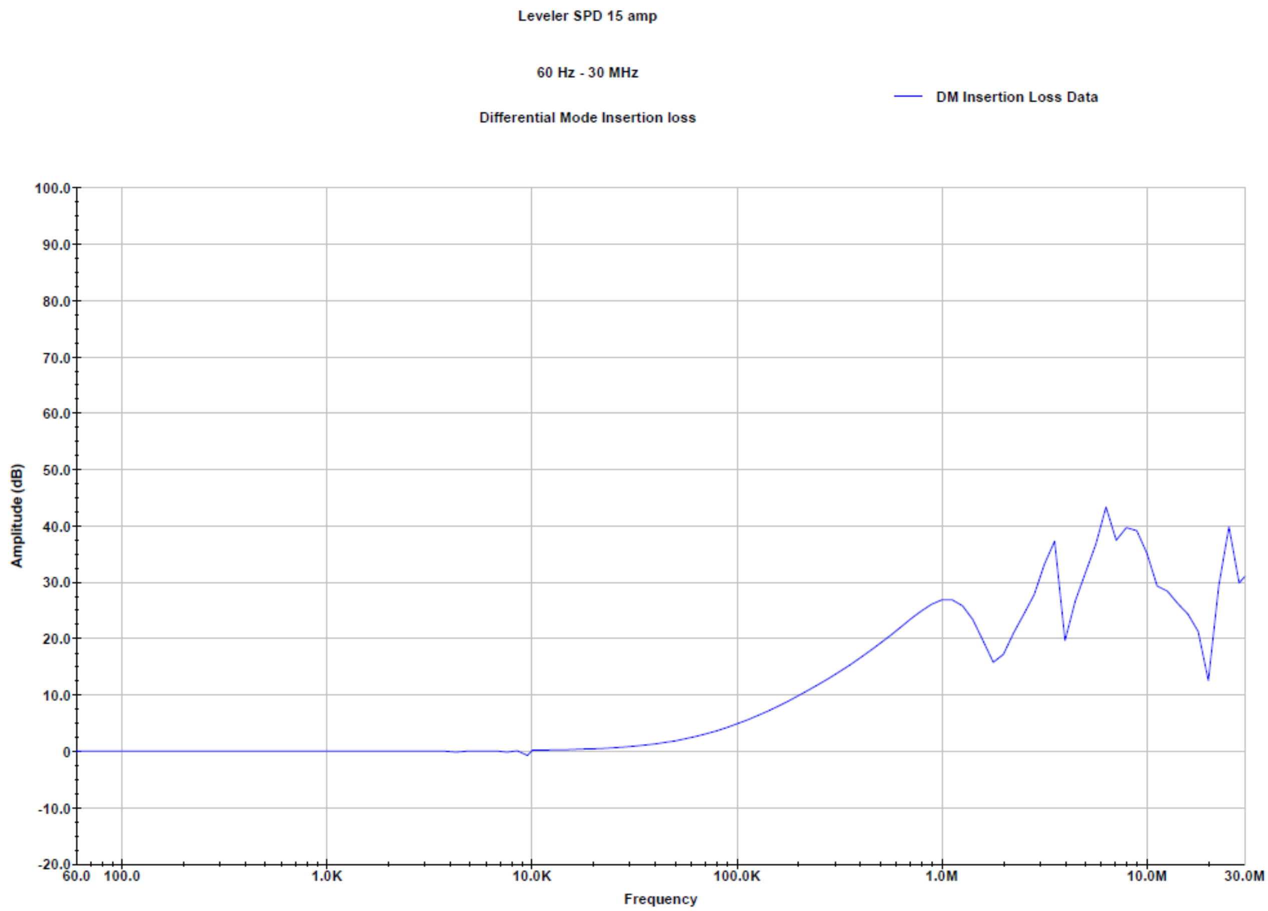

Figure 5-16 Differential Mode Insertion Loss Test Data

6.0 CURRENT HARMONIC SUPPRESSION 30 Hz to 10 kHz

6.1 Purpose

This test is intended to characterize the Leveler SPD's ability to suppress current harmonics produced by load equipment. Test methods have been loosely based on the current harmonics emissions tests described in MIL-STD-1399 section 300B as well as Test method CE101 in MIL-STD-461.

6.2 Lines Tested

Line (L) and Neutral (N) will be evaluated during this test.

6.3 Test Equipment

Table 6-1 Current Harmonic Suppression Test Equipment

Item Description	Frequency Range	Manufacturer/Model No.	Quantity
Current Probe	10 Hz- 500 kHz	FCC F-14	1
Spectrum Analyzer	3 Hz – 26.5 GHz	Agilent/E4440A	1
Variable Load	0 – 100 Ohm	N/A	1

6.4 Test Setup

A programmable power source was used to generate a 115 VAC 60 Hz square wave signal the square wave signal will produce rich harmonic content over the test frequency range, and provide a strong reference to determine the Leveler SPD's harmonic suppression characteristics.

An adjustable resistive load will be used to set various load settings during each test in order to show performance changes with relation to load.

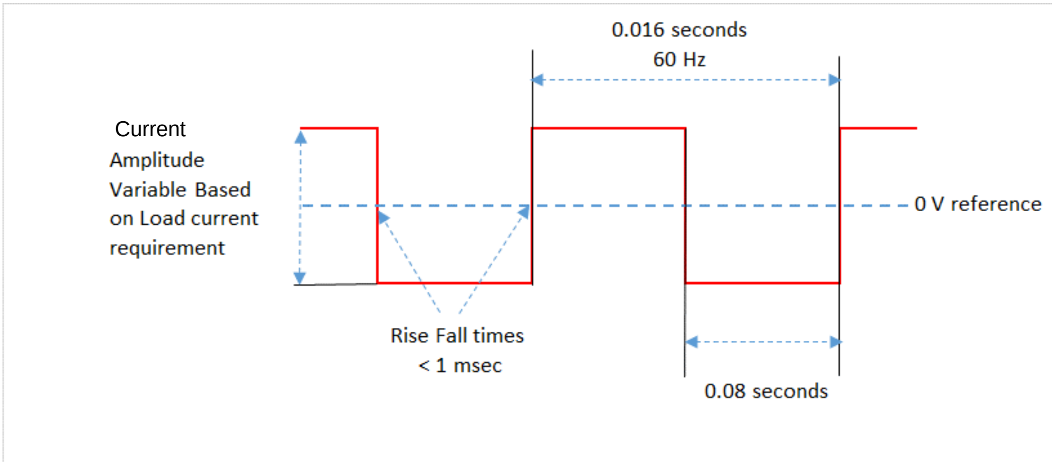

Figure 6-1 Square wave characteristics

6.5 Test Procedure

A baseline measurement shall be performed in order to establish the maximum amount of harmonic content produced from a square wave signal driven into a resistive load shown in Figure 6-1. This measurement is performed without the Leveler SPD in place.

1. The variable resistive load bank should be adjusted to 57.5 ohms. At 115 VAC, this should sink 2 amps worth of current at 230Watts. Verify the load is capable of handling this before applying power.
2. Place the current probe around one line at a time and 5 cm around from variable load.
3. The square wave power source is turned on, and sufficient time is allowed for stabilization.
4. The measurement receiver is scanned over the frequency range of 60 Hz to 10 kHz, using the bandwidths and minimum measurement times specified in MIL-STD-46.
    a. 10 Hz resolution band width is used from 30 Hz to 1 KHz, and 100 Hz resolution band width is used from 1 kHz to 30 MHz.
5. Step 4 is repeated for both Line and Neutral leads.
6. Turn off the power source.
7. This process shall be repeated with the variable load set to 15.3 ohms at 862 Watts, as well as 11.5 ohms at 1150 Watts.
8. A final measurement was performed in order to establish the maximum amount of harmonic current suppression the leveler SPD provides. This measurement is performed with the Leveler SPD in place.
9. The variable resistive load bank was adjusted to 57.5 ohms. At 115 VAC, this should sink 2 amps worth of current at 230Watts. Verify the load is capable of handling this before applying power.
10. Place the current probe around one line at a time and 5 cm around from variable load.

11. The square wave power source is turned on, and sufficient time is allowed for stabilization.
12. The measurement receiver is scanned over the frequency range of 30 Hz to 10 kHz, using the bandwidths and minimum measurement times specified in MIL-STD-461
13. Step 4 is repeated for both Line and Neutral leads.
14. Turn off the power source.
15. This process shall be repeated with the variable load set to 15.3 ohms at 862 Watts, as well as 11.5 ohms at 1150 Watts.

6.6 Test Results

The EUT test results were found consistent and as expected by Leveler engineering.

The test results contain the following information:

- Photograph(s)
- Data Plot(s)

6.7 Analysis

It has been observed that the amount of current harmonic suppression varies based on the load impedance (current draw). In all cases, no suppression of the 60 Hz fundamental current was observed (as expected).
While under a 2 amp load, the current harmonic suppression appeared the greatest above 1 kHz. However, the suppression performance appears to decay as the current draw increases. At a 5 amp draw, harmonic suppression is reduced to a decibel at 1 kHz, and no suppression is observed at a current draw of 10 amps until around 6 kHz.

6.8 Current Harmonic Suppression Photographs

Figure 6-2 Current Harmonic Suppression Baseline setup

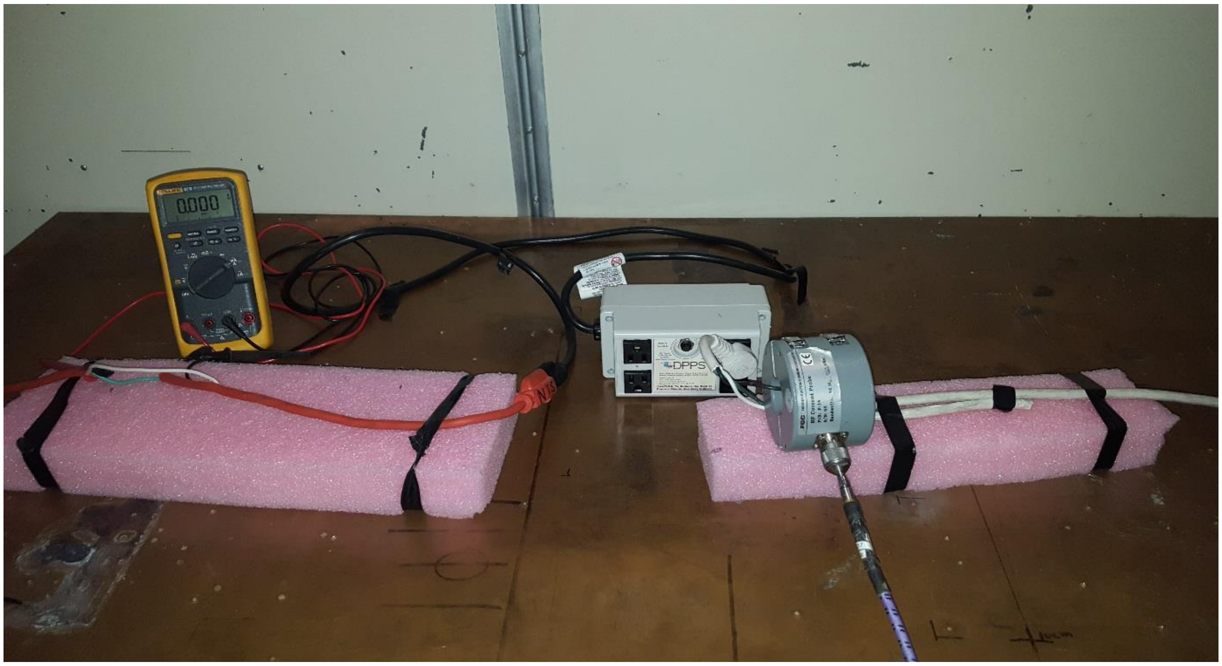

Figure 6-3 Current Harmonic Suppression Test setup

6.9 Current Harmonic Suppression Test Data

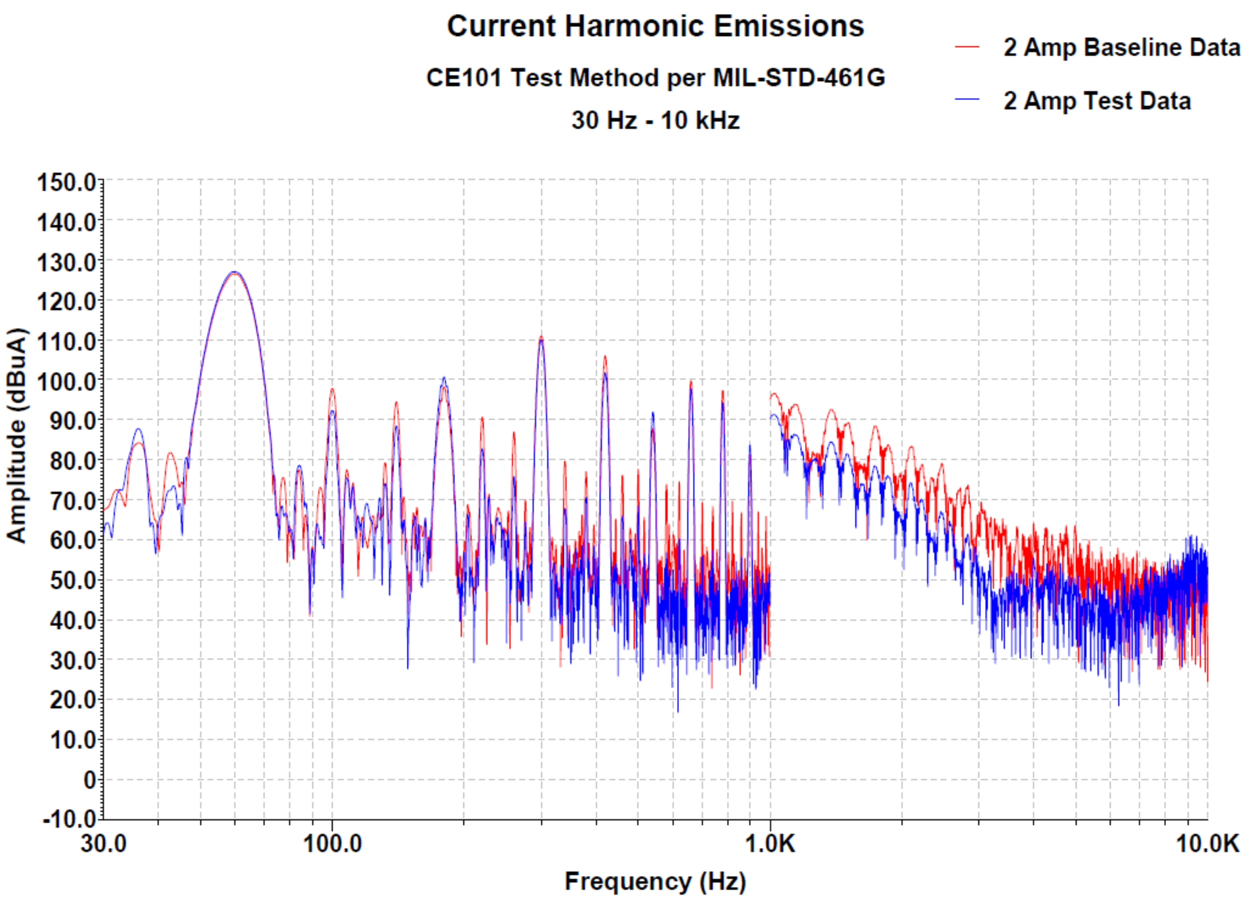

Figure 6-4 Current Harmonic Suppression Test Data 2 amp load

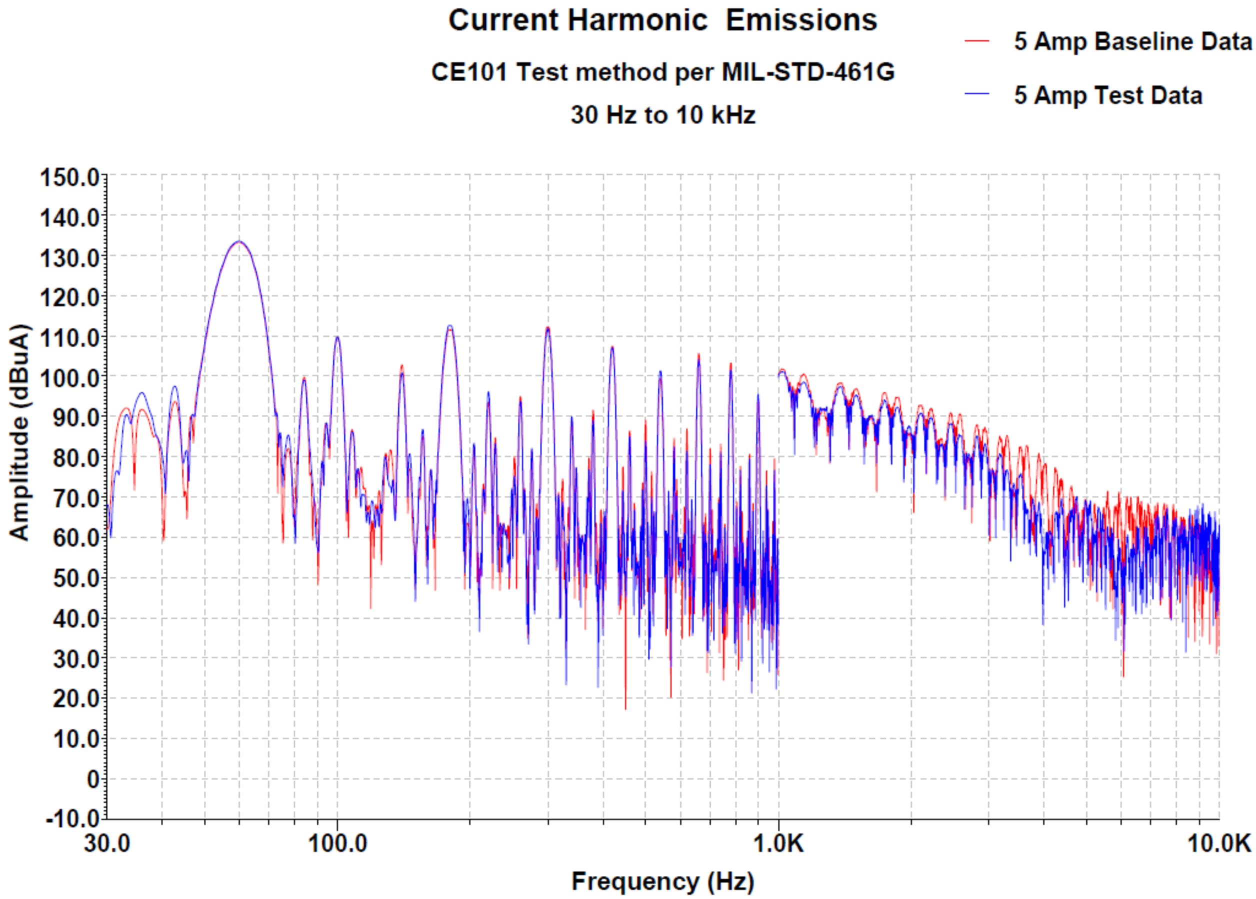

Figure 6-5 Current Harmonic Suppression Test Data 5 amp load

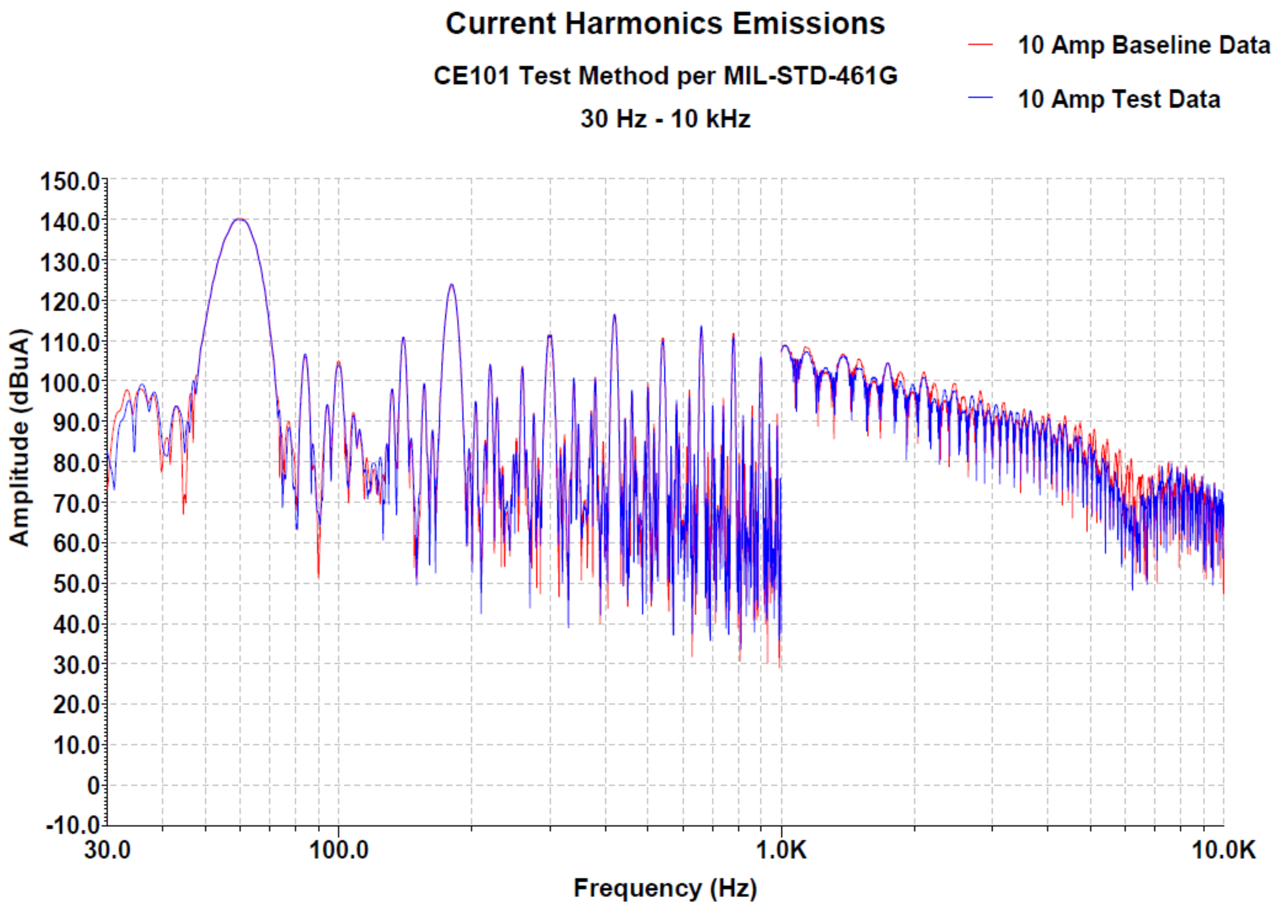

Figure 6-6 Current Harmonic Suppression Test Data 10 amp load

End of Report