SANDIA REPORT

SAND2017-7767
Unlimited Release
Printed July 2017

SHDAS Production Digitizer Evaluation

B. John Merchant

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Issued by Sandia National Laboratories, operated for the United States Department of Energy by National Technology and Engineering Solutions of Sandia, LLC.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865) 576-8401
Facsimile: (865) 576-5728
E-Mail: reports@osti.gov
Online ordering: http://www.osti.gov/scitech

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Rd
Alexandria, VA 22312

Telephone: (800) 553-6847
Facsimile: (703) 605-6900
E-Mail: orders@ntis.gov
Online order: http://www.ntis.gov/search

SAND2017-7767
Unlimited Release
Printed July 2017

SHDAS Production Digitizer Evaluation

B. John Merchant
Ground-Based Monitoring R&E
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-MS0404

Abstract

The Seismo-Hydroacoustic Data Acquisition System (SHDAS) is undergoing evaluation in preparation for its engineering, development, and deployment by the U.S Navy as an ocean bottom seismic monitoring system. At the current stage of development, the production digitizers are being evaluated to confirm their performance prior to packaging and assembly for deployment. The testing of the digitizers is being conducted at Delta Group Electronics, the digitizer fabricator, in San Diego, California, performed by Sandia National Laboratories with the assistance of Leidos and Delta Group Electronics.

1 ACKNOWLEDGMENTS

This work was funded by the United States Air Force and was executed in cooperation with the US Air Force, US Navy, Leidos, Delta Group Electronics, and RPKromer Consulting.

2 CONTENTS

3 FIGURES

4 TABLES

NOMENCLATURE

BB	Broadband
dB	Decibel
DOE	Department of Energy
DWR	Digital Waveform Recorder
GEQ	Geophysical Equipment Qualification
HNM	High Noise Model
LNM	Low Noise Model
OBS	Ocean Bottom Seismometer
PSL	Primary Standards Laboratory
PQ	Production Qualification
SNL	Sandia National Laboratories
SNIB	Sensor Node Interface Blade
SNIT	Sensor Node Interface Timing
SP	Short-period
UP	Underwater Platform

1 INTRODUCTION

Evaluation of the SHDAS digitizers was performed to determine the performance characteristics of the production digitizers that are to be used.

The SHDAS will include a total of 18 Underwater Platform packages. Each package will contain a single digitizer with a total of 7 recording channels (3 channels for the Nanometrics Trillium OBS, 3 channels for the Navy OBS, and 1 channel for the hydroacoustic sensors). Each channel will have a sample rate, sensitivity, noise level, and full scale that are appropriate to the intended sensor. The digitizer on the Underwater Platform will also contain a calibrator and separate monitor channels that may be commanded to be directed to any of the onboard seismometer and/or looped back to a digitizer input channel.

The SHDAS DWR is powered off of a Laboratory DC Power Supply and connected to a prototype equipment rack comprising the necessary shore-side equipment to communicate with the DWR and provide relevant timing information.

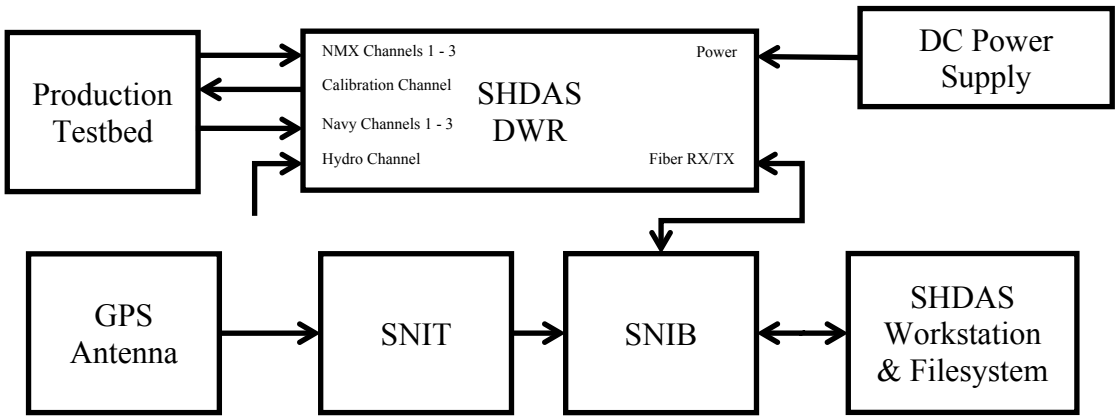


Figure 1 SHDAS Production Testing Block Diagram

This evaluation will not examine the functionality or performance of the hydroacoustic channel due to its unique characteristics that are intended to measure a variable capacitance transducer. This measurement method is outside the scope of this testing.

Evaluation of the SHDAS digitizers will be focused on full production level testing of all digitizers, examining the following characteristics of each of the Nanometrics and Navy OBS digitizer channels:

- Input Impedance
- Sensitivity
- Self-Noise
- Full Scale
- Dynamic Range
- Response
- Passband

- Linearity
- Timing Accuracy

In addition, sample production level testing of a subset of the production digitizers may be performed. Selection of the sample production tests and the digitizers that are tested to this level will be made at Sandia's discretion. These tests include:

- Crosstalk

The monitor channel of the SHDAS digitizer is used as the reference for all future in-field system calibrations. Therefore, calibration of the monitor channel is necessary to allow for comparisons between the nominal calibrations performed during production testing and in-field calibrations. The following characteristics of the monitor channel will be evaluated:

- Sensitivity
- Linearity (Harmonic Distortion)
- Passband

Note that the calibration monitor channel is not externally accessible. Therefore, its performance may only be determined by synchronously recording the output of the calibration signal generator line while that line is simultaneously being routed to the monitor channel by relays within the SHDAS DWR.

General characteristics of the calibration signal generator will be validated:

- Calibrator Consistency
- Linearity (Tone – Harmonic Distortion)
- PRNG Characteristics

2 TEST PLAN

The intended configuration of the digitizer channels is included in the table below. These values were obtained from manufacturer datasheets or provided to Sandia by the Navy from the initial prototype design and may be subject to revision.

Channels	Sample Rate	Calibration Frequency	Sensor Impedance	Sensor Bandwidth (Hz)	Digitizer Bandwidth (HZ) *1	Sensitivity	Digitizer Full Scale (Vpp)	Sensor Full Scale	Expected Digitizer Noise (dB V^2/Hz)
Trillium 1 – BHZ 2 – BH2 3 – BH1	100 Hz	10 Hz	100 ohm	0.02 – 40	3.2 - 40	0.6993 nV/cnt	2.8Vpp @ 10 Hz	40 Vpp	-60 @ 0.02 Hz -80 @ 0.1 Hz -110 @ 1 Hz -140 @ 10 Hz -144 @ 40 Hz
Geophone 1 – SHZ 2 – SH2 3 – SH1	100 Hz	10 Hz	100 kohm	1 - 40	0.02 - 40	0.3215 nV/cnt	1.3 Vpp	100 Vpp *2	-150 @ 1 Hz -156 @ 10 Hz -157 @ 40 Hz
Calibration Monitor	100 Hz	10 Hz	N/A	0.02– 40	0.02 - 40	0.388 nV/cnt	15 Vpp @ 0.02 Hz 3.7 Vpp @ 0.1 Hz 1.67 Vpp @ > 1 Hz	N/A	-85 @ 0.01 Hz -118 @ 0.1 Hz -134 @ 1 Hz -147 @ 10 Hz -151 @ 40 Hz

*1Some of the digitizer bandwidths are intentionally attenuating to reduce expected large signal amplitudes and prevent clipping. The digitizer bandwidth should not be interpreted as the evaluation bounds.

*2 The Geophone OBS full scale value was estimated by converting the nominal full scale displacement to velocity at 10 Hz and scaling by the number of geophones in each axis.

A shore-side installation will provide a time synchronization signal to the digitizers as well as time stamping of the data as it is streamed back. For this reason, testing of the SHDAS digitizers cannot be performed without including a shore interface.

The Navy is responsible for providing the necessary shore interface, operating the digitizer at their facility, and providing Sandia with access to the collected data. Sandia is responsible for generating the reference signals to the digitizer, recording a traceable record of those reference signals, and evaluating the collected data to determine the digitizer performance.

An additional consideration in performing the production testing of the SHDAS digitizers is that the amplifiers within the digitizer may remove DC signals. Therefore, any reference signals used to evaluate the SHDAS digitizer must be AC.

2.1 Evaluation Frequencies

The frequency range of the measurements is from 0.01 Hz to 40 Hz. Specifically, the frequencies from the function below which generates standardized octave-band values in Hz (ANSI S1.6-1984) with F0 = 1 Hz:

$$F(n) = F0 * 10^{(n/10)}$$

For measurements taken using either broadband or tonal signals, the following frequency values shall be used for n = -20, -19, …, 16, 17. The nominal center frequency values, in Hz, are:

> [0.01, 0.0125, 0.016, 0.020, 0.025, 0.0315, 0.040, 0.050, 0.063, 0.08, 0.10, 0.125, 0.16, 0.20, 0.25, 0.315, 0.40, 0.50, 0.63, 0.80, 1.0, 1.25, 1.6, 2.0, 2.5, 3.15, 4.0, 5.0, 6.3, 8.0, 10.0, 12.5, 16, 20, 25, 31.5, 40]

2.2 Test bed

The test bed that Sandia will use for performing production evaluation of the SHDAS digitizers will leverage the test equipment developed by RPKromer Consulting for performing the full evaluation of the prototype digitizers. Sandia provided calibration of the test equipment performed by Sandia's Primary Standards Laboratory (PSL) in order to ensure traceability (See Appendix D: Calibration).

The equipment that Sandia will use for reference signal generation and recording include:

- Agilent 3458A #MY45044336 high precision meter with PSL calibration
- Stanford Research Systems DS360 ultra-low distortion signal generator
- Geotech Smart24 digitizer with calibrator output

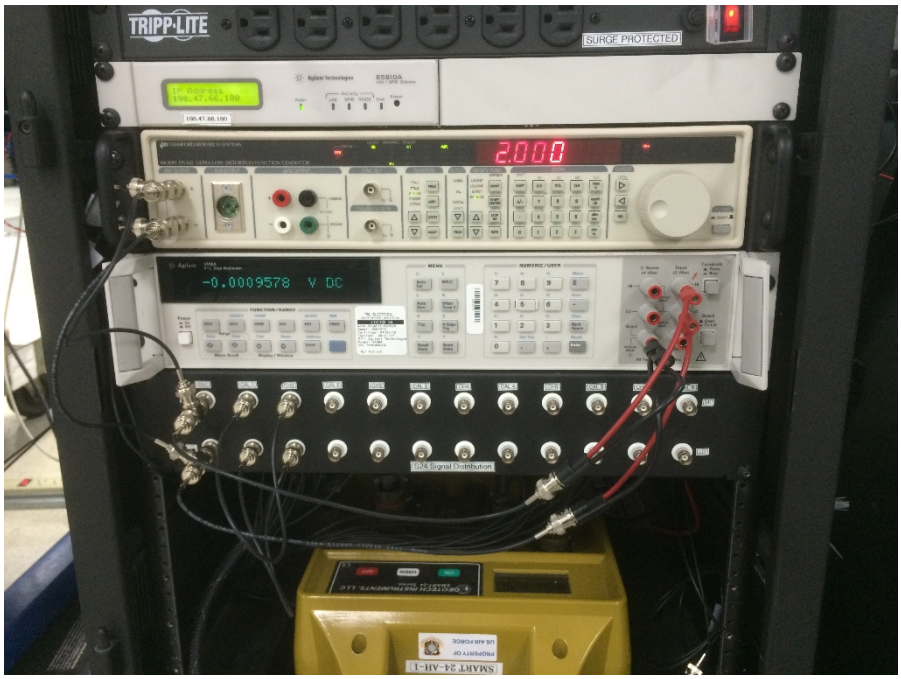


Figure 2 Production Testbed Signal Generation and Recording

The testbed contains two test stations, each with the ability to switch in a resistor in order to perform input-terminated testing. The resistors used on each test station were evaluated using the calibrated reference meter and their values recorded in the table below.

Table 1 Production Test Station Termination Resistors

Channel	Test Station 1	Test Station 2
BHZ	0.1054 kohm	0.1054 kohm
BH2	0.1052 kohm	0.1053 kohm
BH1	0.1053 kohm	0.1053 kohm
SHZ	100.041 kohm	99.960 kohm
SH2	100.017 kohm	100.007 kohm
SH1	100.024 kohm	99.992 kohm

Figure 3 Production Testing Stations

Figure 4 Production Test Station Interface to SHDAS DWR

2.3 Tests

2.3.1 Input Impedance

Purpose: The purpose of the input impedance test is to determine and verify the input impedance of the DWR

Configuration: The DWR inputs are connected to a meter configured to measure resistive impedance.

Evaluation: The measured impedance of the DWR is recorded and compared against the DWR specification.

2.3.2 Sensitivity

Purpose: The purpose of the sensitivity test is to determine and verify the accuracy of the DWR. The bit-weight (LSB) of a non-gain-ranged digitizer is its resolution.

Configuration: The DWR inputs are connected to an AC sinusoid voltage source, usually set to a frequency of the calibration frequency and an amplitude 10% of the DWR full scale.

Evaluation: The accuracy of the DWR, DC offset, bit-weight (LSB)/resolution and counts/volt are measured.

2.3.3 Full Scale

Purpose: The purpose of the full scale test is to determine and verify the maximum signal level of the DWR.

Configuration: The DWR input is connected to an AC voltage source set to the calibration frequency. The amplitude of the sinusoid is set to 100% of the specified full scale voltage of the DWR.

Evaluation: The sinusoid peak voltage is measured and compared against the DWR specified full scale voltage.

2.3.4 Self-Noise

Purpose: The purpose of the self-noise test is to verify the static noise parameters of the DWR. These static parameters are dominated primarily by the random noise generated within the digitizer (self-noise) and from other components within the digitizer package.

Configuration: The DWR inputs are terminated with a resistor matching the nominal impedance of the intended sensor.

Evaluation: A power density spectrum of the input-terminated noise provides a measure of the noise floor of the digitizer. RMS noise in the appropriate bandwidth, short term and long term

stability, relationship to quantizing noise floor and correlated and uncorrelated spurious signals are measured.

2.3.5 Dynamic Range

Purpose: The purpose of the maximum-potential dynamic range test is to measure the "best case" signal-to-noise ratio capability of the DWR. This is the ratio of the largest signal that the DWR can measure without clipping (RMS of a full-scale sinusoid) to the RMS noise of the DWR.

Configuration: The input-terminated noise (ITN) data set and full scale voltage are used.

Evaluation: The Dynamic Range of a DWR is determined by calculating the RMS value of a full-scale sinusoid and dividing by the RMS of the Input Terminated Noise (ITN) test data.

2.3.6 Response Verification

Purpose: The purpose of the relative transfer function test is to determine the relative gain, and phase between channels in a multi-channel DWR.

Configuration: The DWR inputs are connected to a bandwidth-limited Gaussian signal generator. The signal generator output amplitude is set to greater than one-half the full-scale range of the DWR.

Evaluation: Coherence analysis computation provides a measure of relative gain, and relative phase. Channel to channel time skew is calculated.

2.3.7 Passband

Purpose: The purpose of the analog bandwidth test is to verify the bandwidth of the DWR analog/digital filter.

Configuration: The DWR inputs are connected to a bandwidth-limited Gaussian signal generator.

Evaluation: A power density spectrum provides a measure of the DWR bandwidth. The 3 dB point and relative attenuation at the Nyquist are measured.

2.3.8 Linearity

Purpose: The purpose of the linearity test is to verify the linearity and to identify sources of non-linearities of the DWR.

Configuration: The DWR inputs are connected to an ultra-low-distortion oscillator. The amplitude of the oscillator is set to 10% full-scale of the DWR. The frequency of the oscillator is set to a frequency unrelated to the sample rate and with nine or more harmonics observable.

Evaluation: A power density spectrum provides a measure of the non-linearity of the DWR. THD is calculated by integrating the power density spectral peaks at the fundamental and all harmonics (up to nine) below the Nyquist frequency.

2.3.9 Timing Accuracy

Purpose: The purpose of the timing accuracy test is to verify the ability of the DWR to accurately time-tag the data samples with respect to the DWR inputs.

Configuration: The DWR inputs are connected to a sinusoid with known phase-alignment synchronized in time.

Evaluation: The time-tags of the data from the DWR are analyzed for correct time on the hour and minute transitions.

2.3.10 Calibrator

Purpose: The purpose of the calibrator amplitude test is to determine and verify if the DWR accurately programs the correct signals for sensor calibrations.

Configuration: The DWR calibrator output is connected to a signal source measurement system. The signal output of the DWR calibrator is set to known levels.

Evaluation: Measured signals are compared to the programmed signals.

2.3.11 Crosstalk

Purpose: The purpose of the crosstalk test is to determine the extent of crosstalk between channels on a multi-channel DWR.

Configuration: The DWR channel under test is terminated with a resistor matching the nominal impedance of the intended sensor. All other DWR inputs are connected to a large amplitude sinusoidal test signal.

Evaluation: A power density spectrum provides a measure of crosstalk. The ratio of test signal to crosstalk signal is calculated using integrated power density spectra around the test signal frequency.

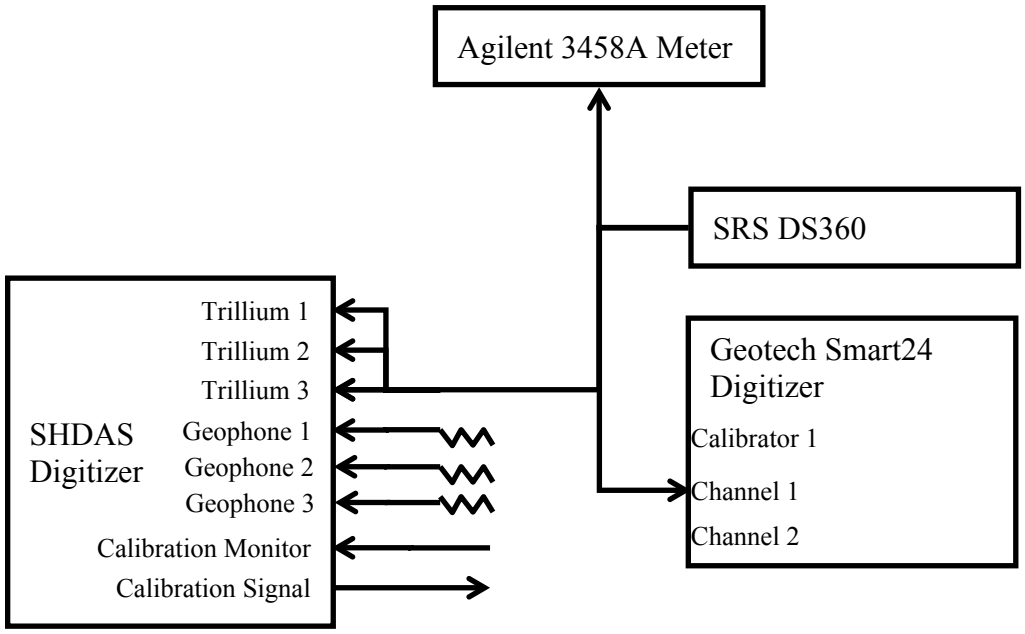
2.4 Procedure

This procedure describes how the testing of each SHDAS digitizer will be performed. An attempt has been made to organize the test execution so as to minimize the number of times that physical connections must be changed.

Note that depending upon the recommendation of the fabrication contractor, the SHDAS digitizer may need to be powered off prior to disconnecting and reconnecting any connectors. Powering off and on, if necessary, is assumed in any step that involves changing connections.

1. Power on the SHDAS DWR and wait a sufficient amount of time for the equipment to thermally equilibrate.

2. Connect the output of the SRS DS360 Ultra Low Distortion oscillator to the Agilent 3458A reference meter (500 Hz), the Geotech Smart24 Digitizer Input Channel 1 (200 Hz and 100 Hz), and all 3 Trillium inputs of the SHDAS digitizer under test (100 Hz), as shown in the diagram below. The Geophone inputs will be terminated with a resistor sized to the anticipated sensor load.



Generate the following test signals from the SRS DS360:

- Full Scale, 100% Full Scale
    - SRS-DS360 generate 10 Hz, (2.8Vpp) 1.4 Vp sinusoid for 1 minute
    - Verify signal on DWR and compute sensitivity, relative to HP Meter reference

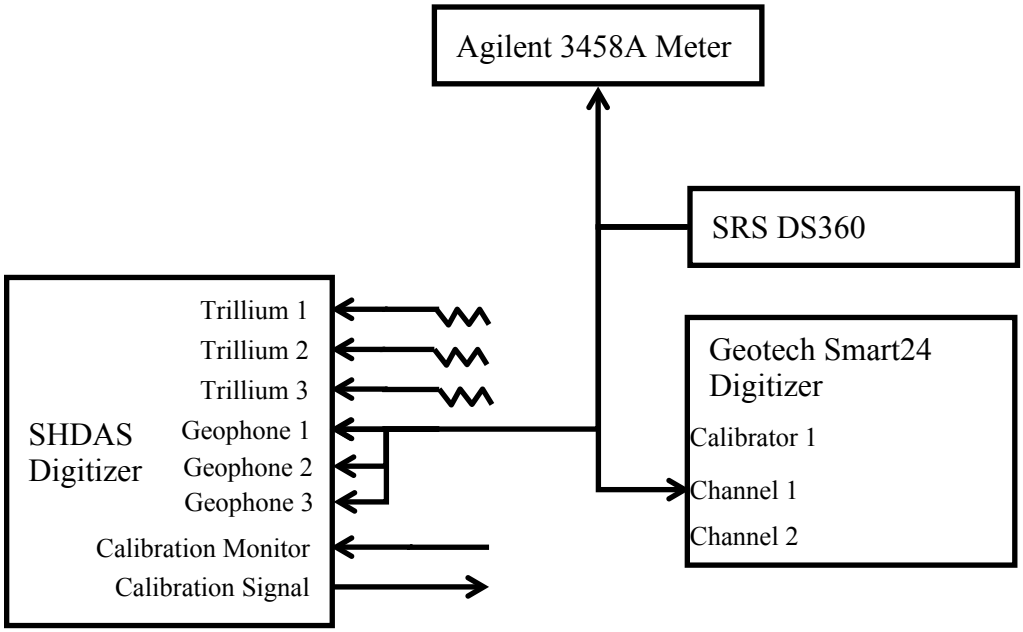
- Large Signal sensitivity, 50% Full Scale
    - SRS-DS360 generate 10 Hz, (1.4Vpp) 0.7 Vp sinusoid for 1 minute

- Verify signal on DWR and compute sensitivity, relative to HP Meter reference

- Small Signal sensitivity, 10% Full Scale
  - SRS-DS360 generate 10 Hz, (0.28 Vpp) 0.14 Vp sinusoid for 1 minute
  - Verify signal on DWR and compute sensitivity, relative to HP Meter reference

- Linearity, 10% Full Scale
  - SRS-DS360 generate 6.28 Hz, (0.28 Vpp) 0.14 Vp sinusoid for 30 minutes
  - Verify signal on DWR and compute THD, relative to the HP Meter

3. Connect the output of the SRS DS360 Ultra Low Distortion oscillator to the Agilent 3458A reference meter (500 Hz), the Geotech Smart24 Digitizer Input Channel 1 (200 Hz and 100 Hz), and all 3 Geophone inputs of the SHDAS digitizer under test (100 Hz), as shown in the diagram below. The Trillium inputs will be terminated with a resistor sized to the anticipated sensor load.



Generate the following test signals from the SRS DS360:

- Full Scale, 100% Full Scale
  - SRS-DS360 generate 10 Hz, (1.3 Vpp) 0.65 Vp sinusoid for 1 minute
  - Verify signal on DWR and compute sensitivity, relative to HP Meter reference

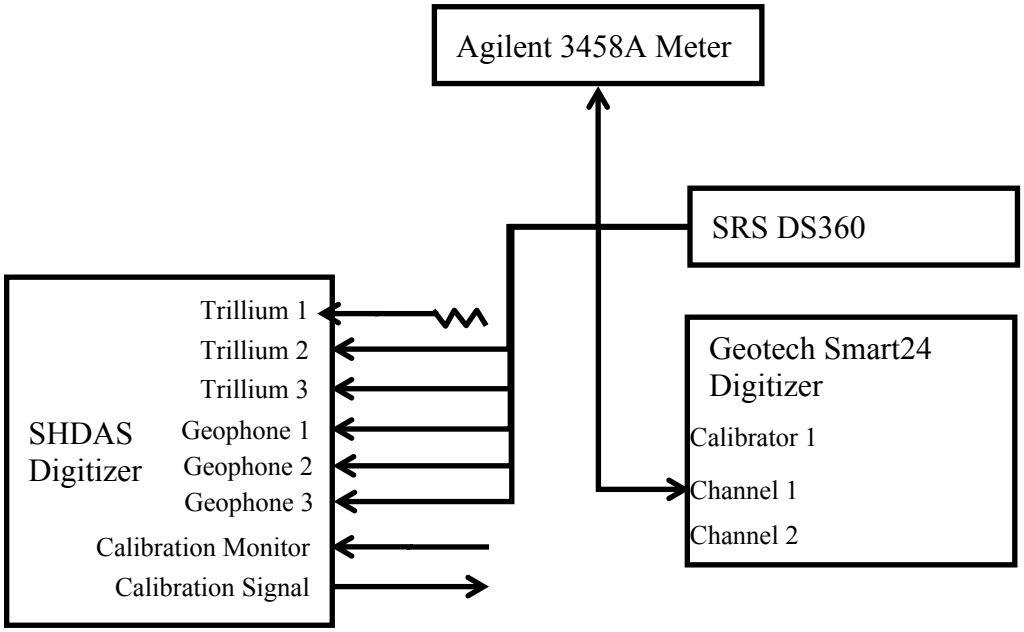
- Large Signal sensitivity, 50% Full Scale
  - SRS-DS360 generate 10 Hz, (0.65 Vpp) 0.325 Vp sinusoid for 1 minute
  - Verify signal on DWR and compute sensitivity, relative to HP Meter reference

- Small Signal sensitivity, 10% Full Scale
  - SRS-DS360 generate 10 Hz, (0.13 Vpp) 0.065 Vp sinusoid for 1 minute

- Verify signal on DWR and compute sensitivity, relative to HP Meter reference

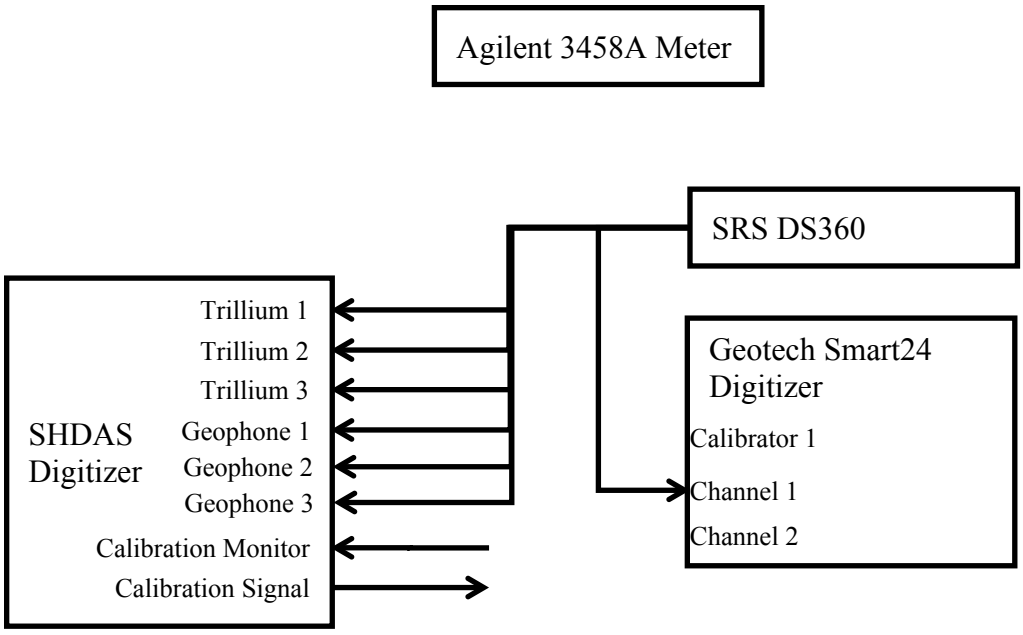
- Linearity, 10% Full Scale
  - SRS-DS360 generate 6.28 Hz, (0.13 Vpp) 0.065 Vp sinusoid for 30 minutes
  - Verify signal on DWR and compute THD, relative to the HP Meter reference

4. Connect the output of the SRS DS360 Ultra Low Distortion oscillator to the Geotech Smart24 Digitizer Input Channel 1 (200 Hz and 100 Hz). Iterate over each of the 6 input channels, connecting the individual input channel to its terminator and the remaining 5 channels are connected to the SRS DS360.



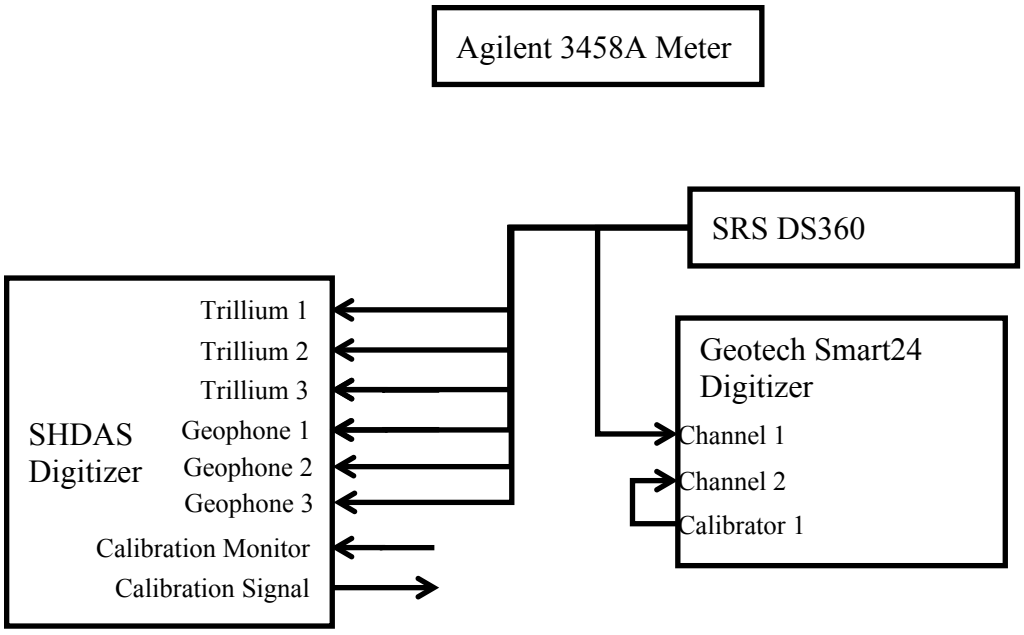
- Crosstalk
  - SRS-DS360 generate 10 Hz, (0.13 Vpp) 0.065 Vp sinusoid for 3 minutes
  - Verify signal on DWR and compute CTK on each tonal channel

5. Connect the output of the SRS DS360 Ultra Low Distortion oscillator simultaneously to all of the SHDAS input channels (100 Hz) and the Geotech Smart24 Digitizer Input Channel 1 (200 Hz and 100 Hz).



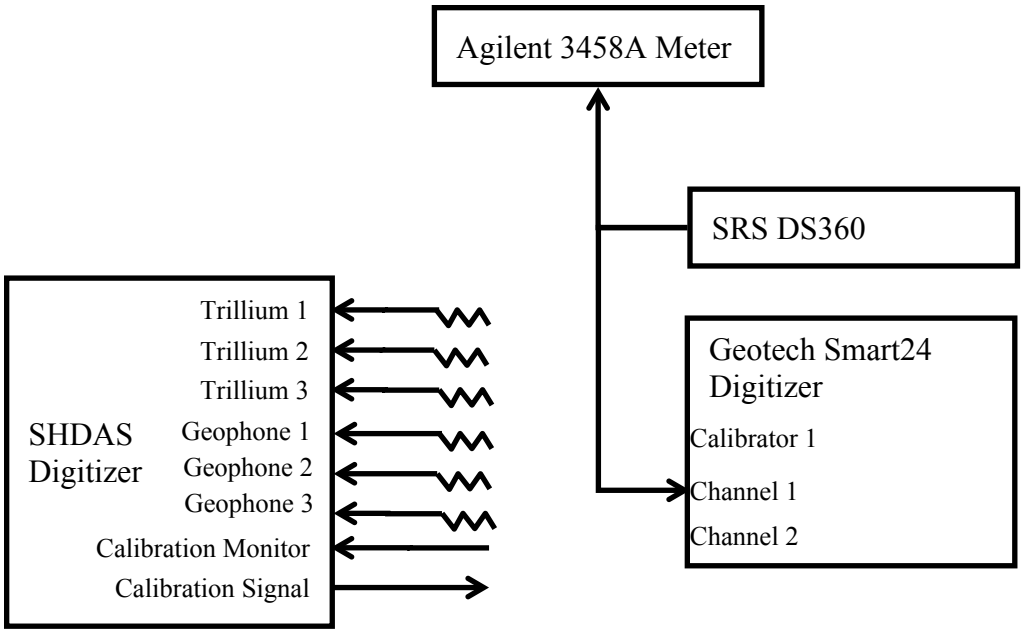
- Response Verification / Passband, 0.5 Vrms
    - SRS-DS360 generate bandlimited white noise, 0.5 Vrms for 12 hours (overnight). Note that due to the wide passband of the SRS-DS360, the actual amplitude within the digitizer passband (< 50 Hz) is significantly less than the specified 0.5 Vrms and is more equivalent to 10% of full scale.
    - Verify signal on DWR and compute amplitude/phase/passband, relative to Smart24

6. Connect the output of the SRS DS360 Ultra Low Distortion oscillator to all 6 digitizer channels in parallel and channel 1 of the Smart24. Connect the output of the Smart24 calibrator to channel 2 of the Smart24.



- Timing Accuracy
    - Generate a 10 Hz, 0.13 Vpp (0.065 Vp) sinusoid on the SRS-DS360, input to the BB and SP channels.
    - Generate a 1 PPM, 1 Vp pulse on the Smart24, looped back to channel 2
    - Simultaneously record 10 minutes 5 Hz sinusoid and 1 PPM pulse on Smart24 for timing reference.
    - Evaluate relative timing between SHDAS DWR and Smart24 using the PPM on the Smart24 as ground-truth.

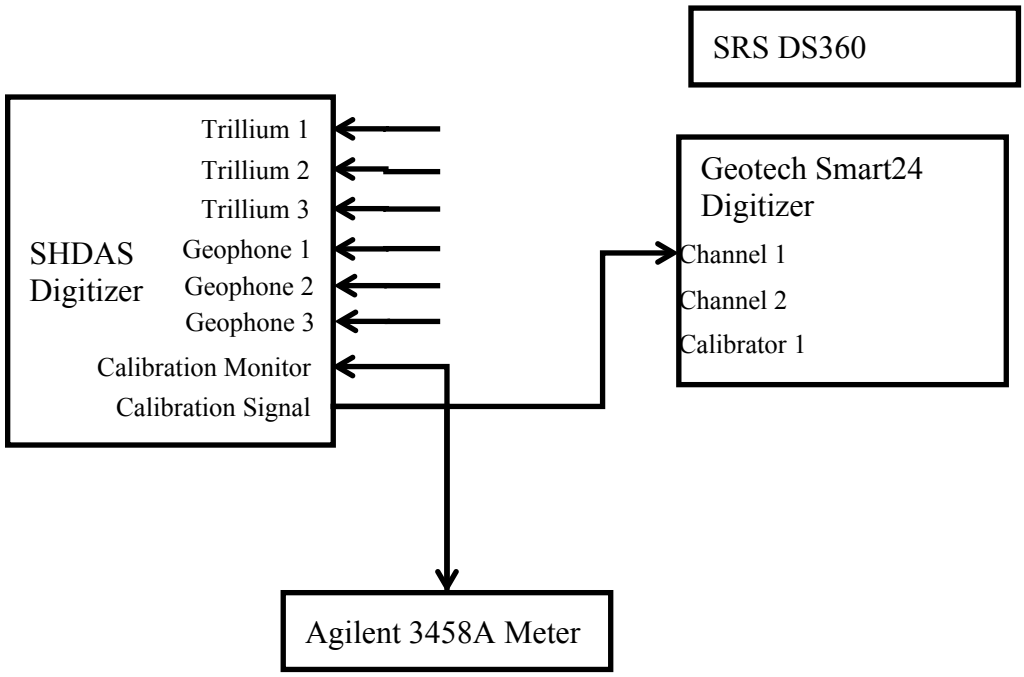
7. Connect input terminators sized to the appropriate sensor for each of the input channels to simulate the presence of a sensor. Collect 12 hours of terminated noise data to be used for self-noise.



Collect the following test signals from the SRS DS360:

- Input Terminated for 12 hours

8. Connect the output of the SHDAS Trillium calibration signal to the Agilent 3458A reference meter (500 Hz) and the Geotech Smart24 Digitizer Input Channel 1 (200 Hz and 100 Hz). Because the calibration signal is single-ended, the High line is connected to the meter high and Smart24 high. The meter low and Smart24 low are tied to ground.



- Tonal Calibration
    - Sensitivity
        - Command the SHDAS Digitizer to generate a 10 Hz tonal calibration signal for 100 seconds at a gain of 12 dB.
        - Verify the signal characteristics are consistent with what is measured on the reference meter
        - Compute calibration monitor channel sensitivity, relative to the reference meter
    - Linearity
        - Command the SHDAS Digitizer to generate a 6.28 Hz tonal calibration signal for 100 seconds at a gain of 12 dB
        - Verify the signal characteristics are consistent with what is measured on the reference meter
        - Compute harmonic distortion, relative to the reference meter.

- PRNG Calibration
    - Command the SHDAS Digitizer to generate a PRNG calibration signal for 100 seconds at a gain of 12 dB.
    - Verify the signal characteristics are consistent with what is measured on the reference meter

3 TEST ENVIRONMENT

Production testing of the SHDAS digitizers took place at Delta Group Electronics in San Diego, CA from June 22, 2016 through September 30, 2016.

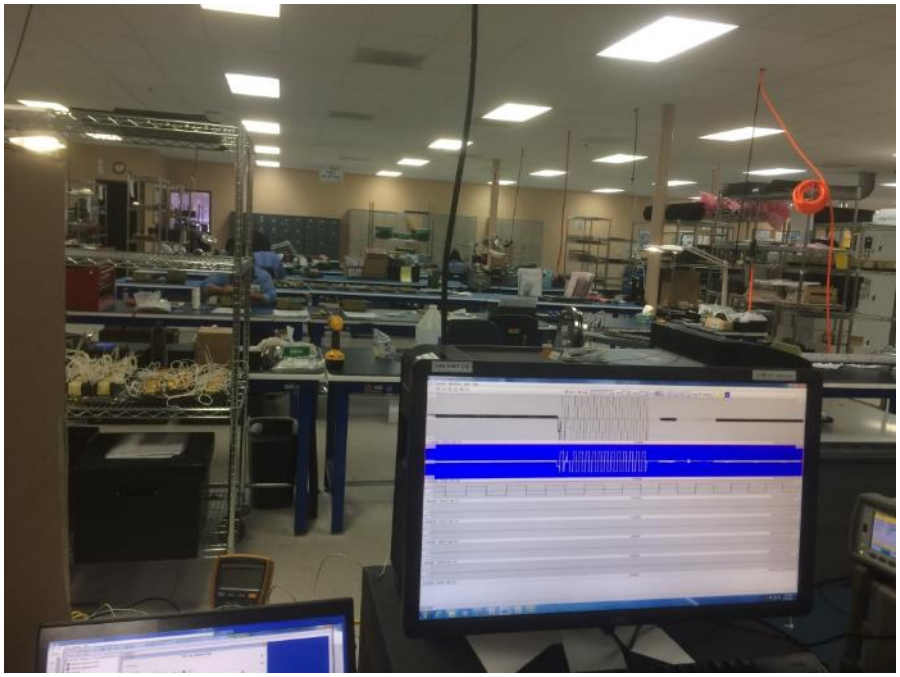


Figure 5 Delta Group Electronics laboratory space

Figure 6 SHDAS digitizer pressure vessels

The digitizers required active cooling in order to maintain a stable temperature that was within the operational limit of the components. It was also desired to operate the equipment at a temperature at or near the expected temperature that had been measured at the intended ocean bottom location of 13 degrees Celsius.

The digitizers were placed within a thick-walled cardboard box with a portable air conditioner blowing into the box. Two thermocouples were placed inside the digitizer pressure vessel to monitor the temperature throughout the testing: One directly on the end cap next to the fiber optic assembly and one suspended in the air inside the vessel. Another thermocouple was kept well outside of the cooling enclosure to monitor the ambient air temperature.

Figure 7 Temperature logger

Figure 8 SHDAS Digitizers and portable air conditioners

Figure 9 Temperature enclosure and cooling system

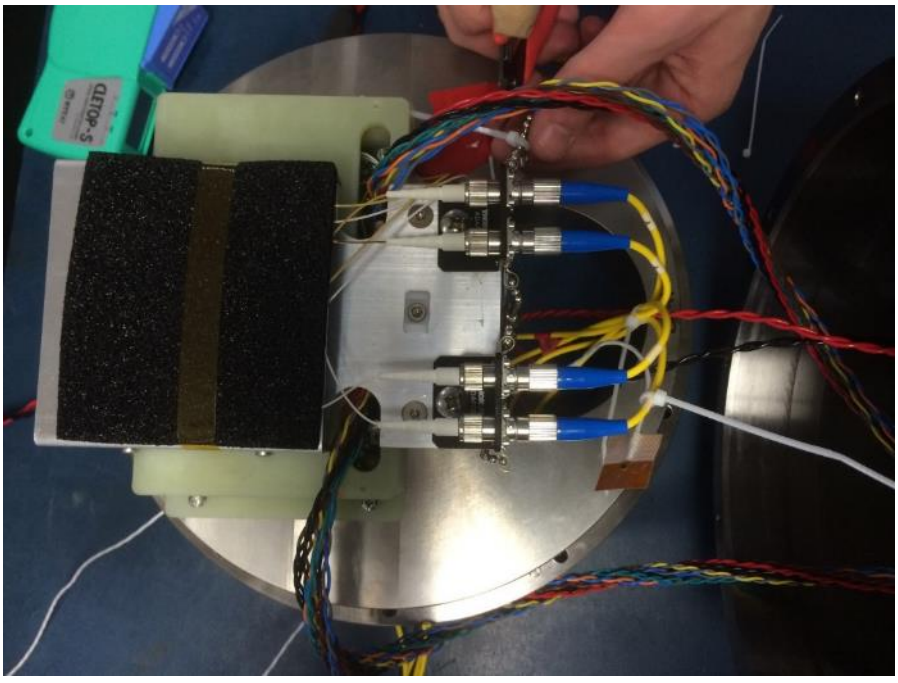


Figure 10 SHDAS DWR Optical Interface

Once each digitizer is powered up and running, it is allowed to thermally stabilize overnight. As may be seen in the plot below of the ambient air temperature, air temperature within the vessel, and end cap temperature, the digitizer needs to stabilize for approximately 6 hours prior to testing commencing.

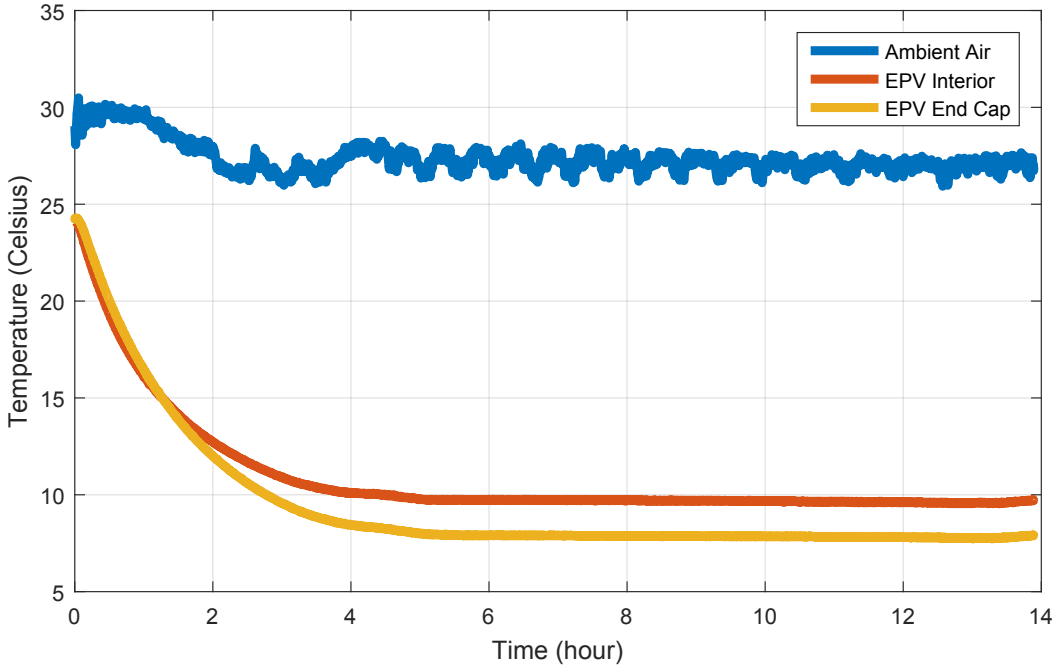


Figure 11 Typical temperature stabilization

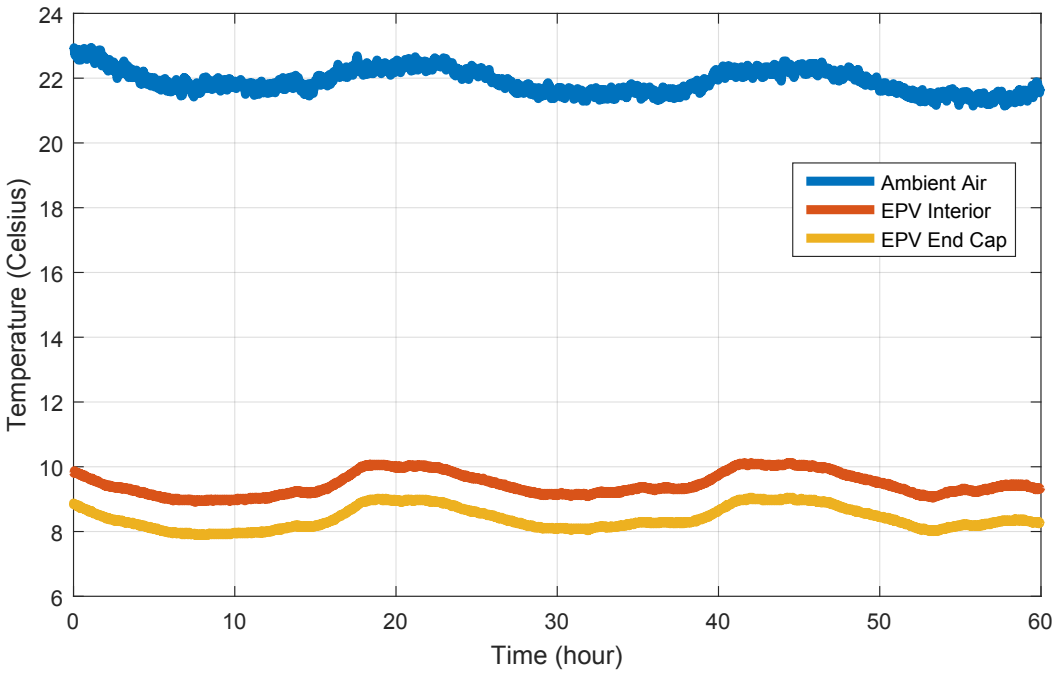


Figure 12 Typical temperature diurnal cycle

Measurements of temperature were recorded continuously during testing. A summary of the temperature conditions for each digitizer and test are shown in the tables below.

Table 2 Ambient Air Temperature

Digitizer	Impedance	BB Full Scale / Sensitivity / Linearity	SP Full Scale / Sensitivity / Linearity	Crosstalk	Timing	Calibrator	Response	Self-Noise
# 1	22.7 C	23.0 C	23.1 C	23.4 C	23.3 C	23.2 C	23.6 C	22.3 C
# 2	24.2 C	24.2 C	24.1 C	24.7 C	24.6 C	25.2 C	24.8 C	25.1 C
# 3	22.4 C	22.4 C	21.7 C	22.2 C	22.9 C	22.9 C	24.9 C	23.5 C
# 4	22.6 C	22.6 C	22.6 C	23.2 C	23.6 C	23.6 C	24.0 C	23.3 C
# 5	22.7 C	23.0 C	23.3 C	23.3 C	23.6 C	23.6 C	24.0 C	22.6 C
# 6	22.6 C	22.7 C	22.8 C	23.4 C	23.2 C	22.8 C	22.6 C	22.4 C
# 7	22.7 C	22.4 C	22.7 C	23.3 C	23.0 C	23.1 C	23.1 C	22.8 C
# 8	22.9 C	23.0 C	23.3 C	23.3 C	23.6 C	24.0 C	24.0 C	22.6 C
# 9	23.1 C	23.1 C	23.3 C	23.3 C	23.2 C	23.3 C	23.6 C	23.3 C
# 10	21.5 C	21.8 C	22.2 C	22.6 C	22.6 C	22.9 C	23.2 C	24.2 C
# 11	21.4 C	21.8 C	22.2 C	22.6 C	22.6 C	23.0 C	23.2 C	23.1 C
# 12	22.0 C	22.3 C	22.4 C	22.9 C	22.5 C	23.0 C	23.4 C	22.1 C
# 13	22.6 C	23.0 C	23.1 C	23.4 C	23.3 C	23.3 C	23.6 C	22.3 C
# 14	23.6 C	23.5 C	23.9 C	24.4 C	24.7 C	24.8 C	24.4 C	24.2 C
# 15	23.5 C	23.5 C	23.9 C	24.4 C	24.7 C	24.6 C	24.4 C	24.1 C
# 16	22.5 C	22.8 C	23.5 C	23.9 C	23.5 C	23.7 C	23.6 C	23.4 C
# 17	21.9 C	22.0 C	22.2 C	22.7 C	23.3 C	23.1 C	23.1 C	22.7 C
# 18	22.1 C	22.3 C	22.4 C	22.9 C	22.5 C	22.9 C	23.4 C	22.1 C

Table 3 Pressure Vessel Air Temperature

Digitizer	Impedance	BB Full Scale / Sensitivity / Linearity	SP Full Scale / Sensitivity / Linearity	Crosstalk	Timing	Calibrator	Response	Self-Noise
# 1	12.3 C	12.4 C	10.5 C	9.4 C	9.5 C	9.6 C	8.7 C	12.3 C
# 2	11.1 C	11.1 C	11.6 C	11.8 C	11.9 C	11.9 C	12.0 C	12.0 C
# 3	10.4 C	10.4 C	10.2 C	10.3 C	10.6 C	10.4 C	11.9 C	9.8 C
# 4	9.2 C	9.2 C	9.4 C	9.7 C	9.8 C	9.9 C	9.9 C	9.8 C
# 5	7.8 C	8.1 C	8.3 C	8.5 C	8.6 C	8.8 C	7.8 C	6.8 C
# 6	13.4 C	13.5 C	13.6 C	13.5 C	14.3 C	14.2 C	13.4 C	13 C
# 7	9.1 C	8.9 C	9.4 C	8.8 C	8.6 C	8.4 C	8.2 C	8.7 C
# 8	6.6 C	6.7 C	6.9 C	7.1 C	7.2 C	7.4 C	6.3 C	5.5 C
# 9	9.1 C	9.1 C	9.4 C	9.5 C	9.5 C	9.5 C	9.9 C	9.6 C
# 10	9.1 C	9.2 C	9.0 C	9.0 C	9.1 C	9.2 C	9.3 C	10.6 C
# 11	7.0 C	7.1 C	7.1 C	7.2 C	7.4 C	7.6 C	7.9 C	8.0 C
# 12	8.5 C	8.6 C	8.9 C	9.2 C	9.5 C	9.4 C	9.4 C	8.8 C
# 13	8.3 C	8.5 C	8.9 C	9.4 C	9.1 C	8.9 C	9.2 C	7.6 C
# 14	7.4 C	7.7 C	7.9 C	8.3 C	8.4 C	8.5 C	8.5 C	8.0 C
# 15	9.8 C	10.0 C	10.1 C	10.5 C	10.6 C	10.7 C	11.1 C	10.5 C
# 16	6.9 C	7.4 C	7.8 C	8.1 C	8.2 C	8.4 C	8.2 C	10.0 C
# 17	8.1 C	8.2 C	8.5 C	8.8 C	9.3 C	8.9 C	9.3 C	9.4 C
# 18	7.4 C	7.5 C	7.6 C	7.8 C	8.0 C	8.1 C	8.1 C	7.2 C

Table 4 Pressure Vessel End Cap Temperature

Digitizer	Impedance	BB Full Scale / Sensitivity / Linearity	SP Full Scale / Sensitivity / Linearity	Crosstalk	Timing	Calibrator	Response	Self-Noise
# 1	10.9 C	11.2 C	9.0 C	8.7 C	8.8 C	8.9 C	7.5 C	11.2 C
# 2	9.3 C	9.3 C	9.9 C	10.0 C	10.1 C	10.2 C	10.4 C	10.2 C
# 3	8.5 C	8.5 C	8.4 C	8.5 C	8.5 C	8.6 C	10.1 C	8.0 C
# 4	7.9 C	7.9 C	8.1 C	7.9 C	8.5 C	8.7 C	8.5 C	8.6 C
# 5	6.9 C	7.1 C	7.3 C	7.5 C	7.6 C	7.7 C	6.8 C	5.7 C
# 6	7.4 C	7.5 C	7.6 C	7.8 C	8.1 C	8.1 C	7.4 C	7.5 C
# 7	7.3 C	7.1 C	7.7 C	6.9 C	6.7 C	6.4 C	6.5 C	6.8 C
# 8	5.2 C	5.2 C	5.4 C	5.6 C	5.7 C	5.9 C	4.9 C	4.1 C
# 9	8.0 C	8.0 C	8.2 C	8.3 C	8.4 C	8.4 C	8.7 C	8.4 C
# 10	7.8 C	7.9 C	7.8 C	7.8 C	7.9 C	8.0 C	8.2 C	9.5 C
# 11	6.4 C	6.5 C	6.6 C	6.9 C	7.0 C	7.3 C	7.4 C	7.5 C
# 12	7.0 C	7.1 C	7.4 C	7.6 C	7.9 C	7.8 C	7.7 C	7.1 C
# 13	7.6 C	7.8 C	8.2 C	8.1 C	7.8 C	7.6 C	8.6 C	7.6 C
# 14	6.2 C	6.5 C	6.8 C	7.2 C	7.3 C	7.4 C	7.4 C	6.5 C
# 15	7.2 C	7.4 C	7.6 C	8.0 C	8.0 C	8.1 C	8.5 C	8.0 C
# 16	5.9 C	6.1 C	6.5 C	6.8 C	6.9 C	7.1 C	7.1 C	9.8 C
# 17	7.0 C	7.1 C	7.4 C	7.6 C	8.2 C	7.8 C	8.2 C	8.2 C
# 18	5.9 C	5.9 C	6.1 C	6.3 C	6.5 C	6.5 C	6.5 C	5.6 C

4 TEST RESULTS

The digitizers were evaluated at Delta Group Electronics, the contracted fabricator of the digitizers, in San Diego, CA from June 20, 2016 – September 30, 2016. All tests were executed a minimum of two times over separate days to ensure consistency in results. The results reported in this document are from the final iteration of testing when any issues had been corrected and the digitizers have had longer to thermally stabilize.

During the first week of evaluation (June 20 – 25, 2016) a number of issues with the shore-side equipment relating to data drop-outs, data-frame re-arrangement, and timing errors were identified. These issues were corrected by the Leidos team prior to production testing beginning.

4.1 Test schedule and progress

Testing of the specific digitizers was performed according to the table below. Some of the digitizers required multiple evaluations over different time periods as issues were identified and corrected by Leidos or Delta. In addition, any observed issues involved in testing the specific units are detailed in subsequent sections.

Table 5 Digitizer Testing Dates and Configuration

Digitizer	Start Date	End Date	PQ Test Station	SHDAS Station	SNIB #	SNIT #	SDAQ
# 1	9/09/2016	9/12/2016	2	CY201	SN5181	SN10	19
	9/19/2016	9/20/2016	2	CY201	SN5181	SN10	19
# 2	6/22/2016	6/28/2016	2	CY101	SN5182	SN5180	2
# 3	6/29/2016	6/30/2016	2	CY201	SN5181	SN5180	3
# 4	6/30/2016	7/6/2016	1	CY201	SN5181	SN5180	4
# 5	6/30/2016	7/6/2016	2	CY101	SN5182	SN5180	5
	8/25/2016	8/27/2016	1	CY101	SN5182	SN10	5
	9/09/2016	9/12/2016	1	CY101	SN5182	SN10	5
	9/26/2016	9/27/2016	1	CY101	SN5182	SN10	5
# 6	7/6/2016	7/8/2016	1	CY201	SN5181	SN5180	6
# 7	7/6/2016	7/8/2016	2	CY101	SN5182	SN5180	7
	8/25/2016	8/27/2016	2	CY201	SN5181	SN10	7
# 8	7/8/2016	7/12/2016	1	CY201	SN5181	SN5180	8
	9/02/2016	9/06/2016	2	CY201	SN5181	SN10	8
	9/06/2016	9/09/2016	2	CY201	SN5181	SN10	8
	9/26/2016	9/27/2016	2	CY201	SN5181	SN10	8
# 9	7/8/2016	7/12/2016	2	CY101	SN5182	SN5180	9
	8/18/2016	8/24/2016	1	CY101	SN5182	SN10	9
	9/28/2016	9/30/2016	1	CY201	SN5181	SN10	1
# 10	7/12/2016	7/14/2016	1	CY201	SN5181	SN5180	10
# 11	7/12/2016	7/14/2016	2	CY101	SN5182	SN5180	11
# 12	8/23/2016	8/25/2016	1	CY101	SN5182	SN10	12
# 13	8/15/2016	8/16/2016	1	CY101	SN5182	SN10	13
	9/2/2016	9/06/2016	1	CY101	SN5182	SN10	13
	9/19/2016	9/20/2016	1	CY101	SN5182	SN10	13

# 14	8/15/2016	8/18/2016	2	CY201	SN5181	SN10	14
# 15	8/16/2016	8/18/2016	1	CY101	SN5182	SN10	15
# 16	8/18/2016	8/23/2016	2	CY201	SN5181	SN10	16
# 17	8/20/2016	8/23/2016	1	CY101	SN5182	SN10	17
	9/06/2016	9/09/2016	1	CY101	SN5182	SN10	17
# 18	8/23/2016	8/25/2016	2	CY201	SN5181	SN10	18

4.1.1 Digitizer #1

Digitizer #1 was tested from September 9, 2016 to September 12, 2016 and found to have performance that was consistent with the prior GEQ evaluations with the exception of crosstalk on channels SHZ and SH2. Typical crosstalk values on the short-period channels have ranged from -110 to -120 dB. Channels SHZ and SH2 were observed to have crosstalk in the range of -75 dB.

Digitizer #1 was returned to the Leidos team for investigation into the cause of the elevated crosstalk levels. It was identified that the short-period connector on the pressure vessel end-plate was responsible for the elevated crosstalk. The endplate for digitizer #5, which was currently under diagnosis for elevated noise by Leidos, was swapped in to #1. The cross-talk in the end-plate will have to be resolved before #5 can be re-tested.

Digitizer #1 was re-tested from September 19, 2016 to September 20, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on September 20, 2016.

4.1.2 Digitizer #2

Digitizer #2 was tested from June 22, 2016 to June 28, 2016 and found to have performance that was consistent with the prior GEQ evaluations. Input-terminated noise was slightly elevated below 0.1 Hz on the broadband channels, however not excessively so. It was released to the Navy for integration on June 28, 2016.

4.1.3 Digitizer #3

Digitizer #3 was tested from June 29, 2016 to June 30, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on June 30, 2016.

4.1.4 Digitizer #4

Digitizer #4 was tested from June 30, 2016 to July 6, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on July 6, 2016.

4.1.5 Digitizer #5

Digitizer #5 was tested from June 30, 2016 to July 6, 2016 and found to have elevated input terminated noise on channels BH1 and SHZ that was significantly higher than expected. Other than elevated noise, the digitizer performance was consistent with prior GEQ evaluations.

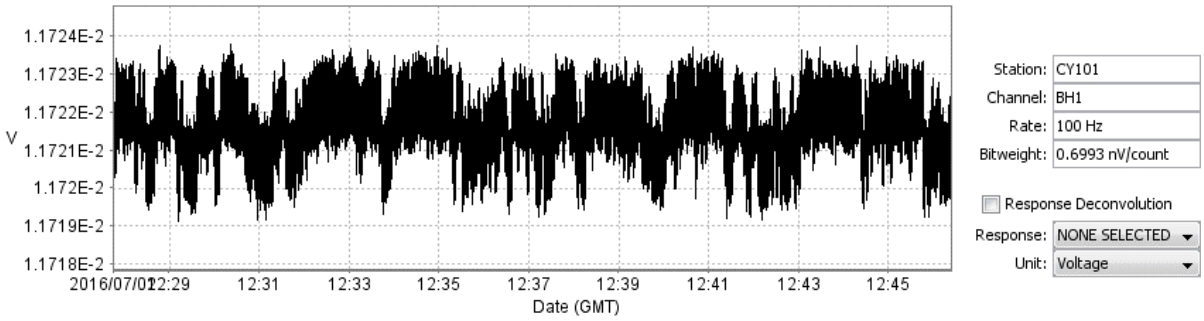


Figure 13 Digitizer #5 Elevated Noise Time Series on BH1

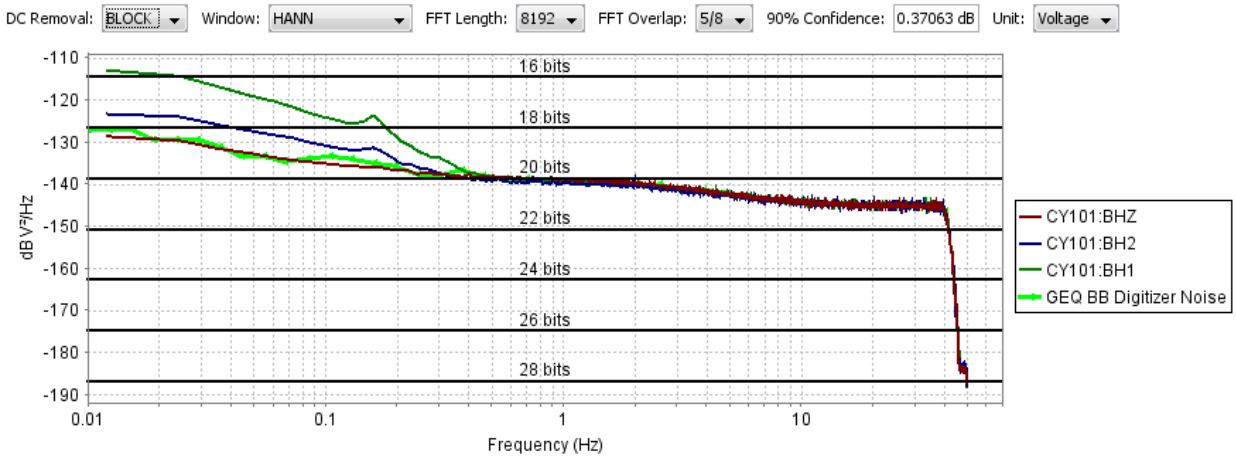


Figure 14 Digitizer #5 Elevated Noise Power Spectra on BH1

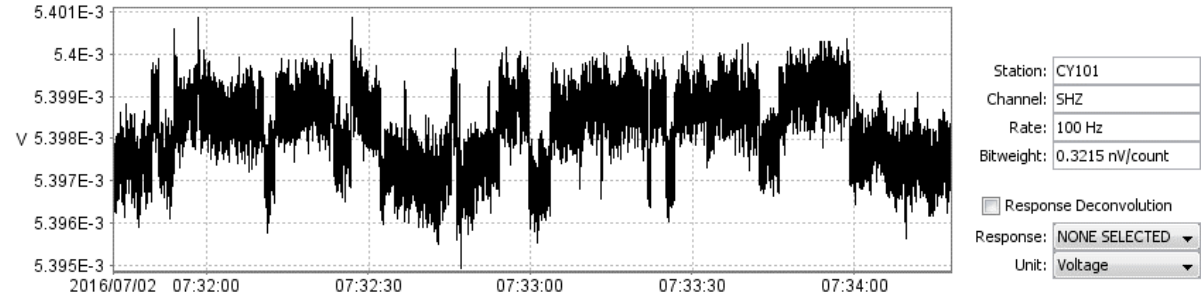


Figure 15 Digitizer #5 Elevated Noise Time Series on SHZ

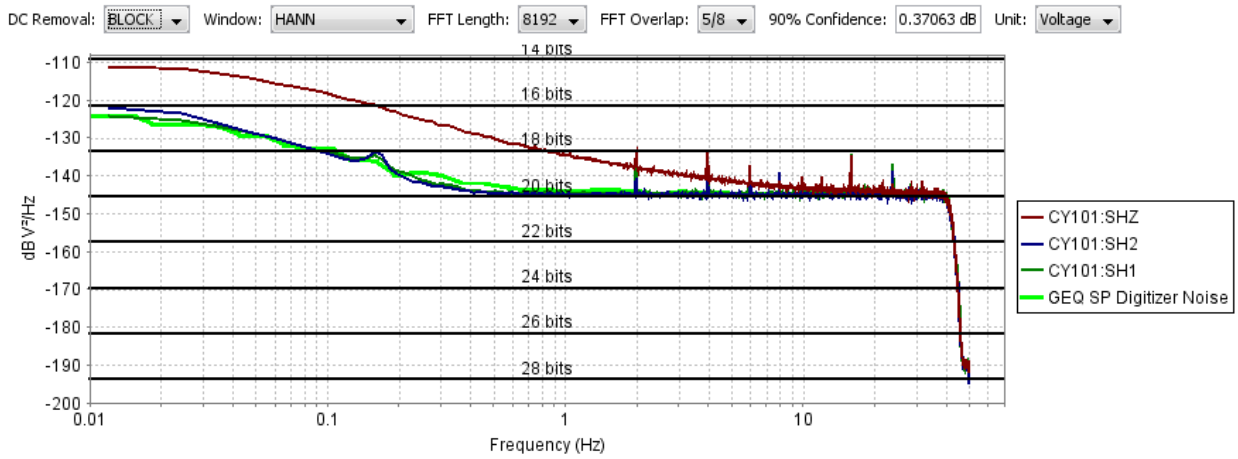


Figure 16 Digitizer #5 Elevated Noise Power Spectra on SHZ

Investigation by Leidos determined the noise issue to be caused by anomalous behavior of the Cirrus Logic CS3301 chips on the analog front-end of these channels. These chips were replaced by Delta on August 23, 2016 and the digitizer was put back in the queue for testing.

Digitizer #5 was re-tested from August 25, 2016 to August 27, 2016 and found that the input-terminated noise on SHZ was corrected. However, the input-terminated noise on BH1 was worse than before. In addition, the timing tests revealed that channels SHZ, SH2, and SH1 now appeared to have a 11.4 millisecond timing offset and channels BHZ, BH2, and BH1 now appeared to have a 1.4 millisecond timing offset.

Digitizer #5 was returned to the Leidos team for further investigation on August 27, 2016. It was determined that a different firmware revision had been loaded onto it for debugging. The correct firmware was re-loaded and the unit put back into the queue for testing.

Digitizer #5 was re-tested from September 9, 2016 to September 12, 2016. The issue with the channel timing appeared to have been resolved. However, there continued to be considerable low frequency noise (< 0.5 Hz) on channel BH1.

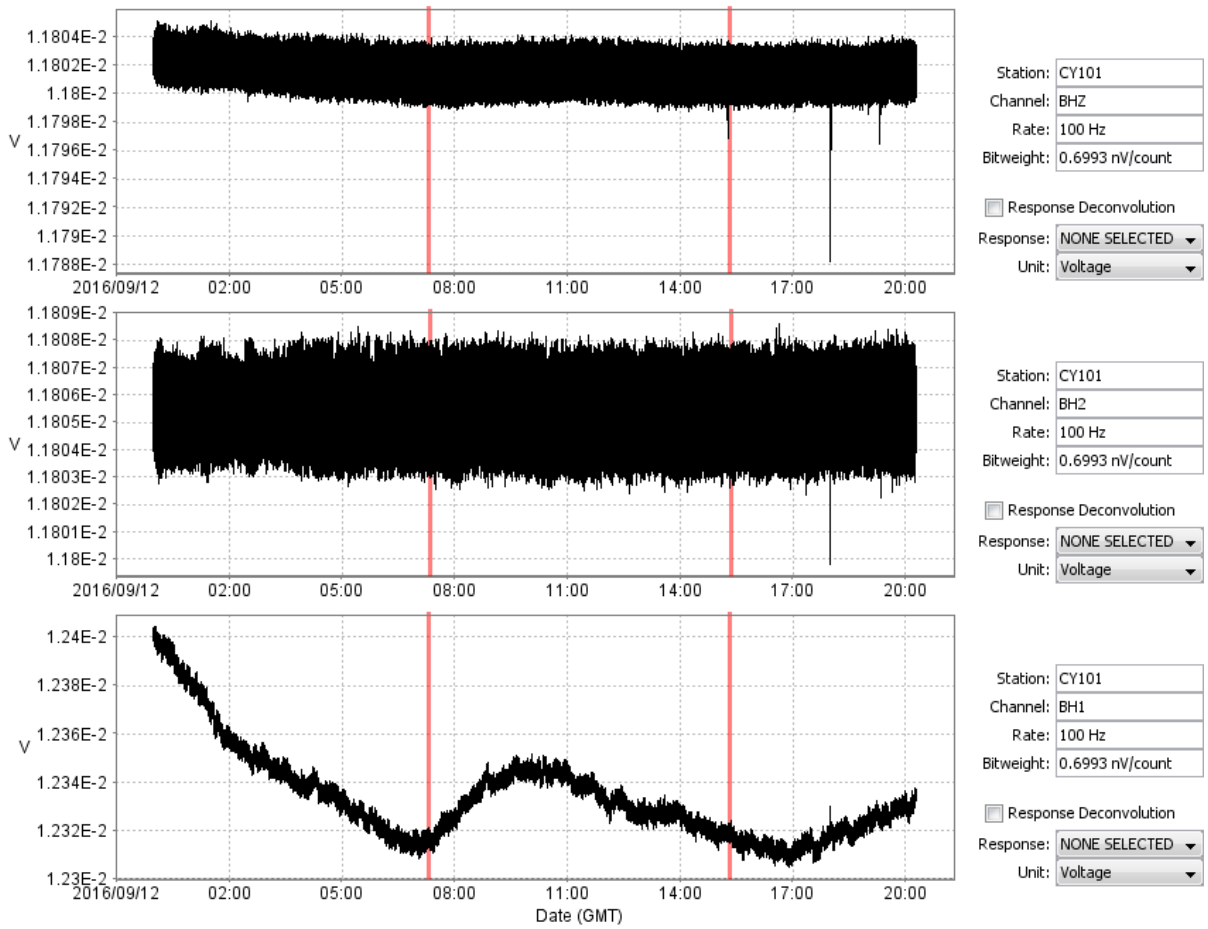


Figure 17 Digitizer #5 Elevated Noise Time Series on BH1

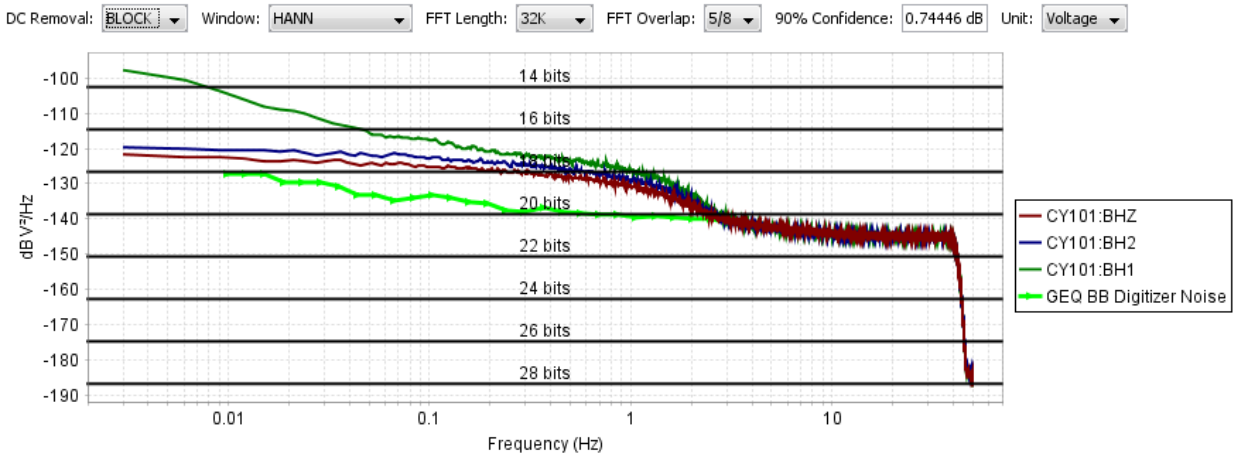


Figure 18 Digitizer #5 Elevated Noise Power Spectra on BH1

Digitizer #5 was returned to the Leidos team for further investigation on September 12, 2016. The conformal coating on the replacement CS3301's was removed, cleaned, and re-coated. In addition, diagnosis and replacement of the short-period connector of the end-plate that came from #1 was performed. The replacement of the connector solved the problem with crosstalk.

Digitizer #5 was re-tested from September 27, 2016 to September 28, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on September 28, 2016.

4.1.6 Digitizer #6

Digitizer #6 was tested from July 6, 2016 to July 8, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on July 8, 2016.

4.1.7 Digitizer #7

Digitizer #7 was tested from July 6, 2016 to July 8, 2016 and found to have elevated input terminated noise on channel SH1 that was significantly higher than expected. Other than elevated noise, the digitizer performance was consistent with prior GEQ evaluations.

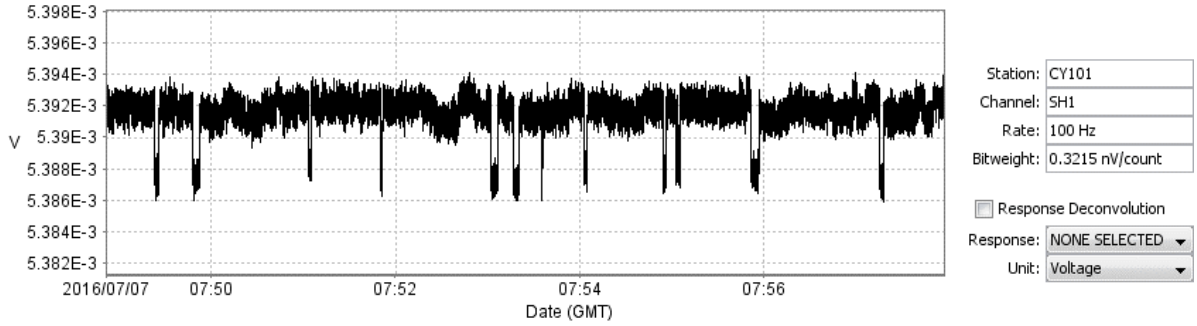


Figure 19 Digitizer #7 Elevated Noise Time Series on SH1

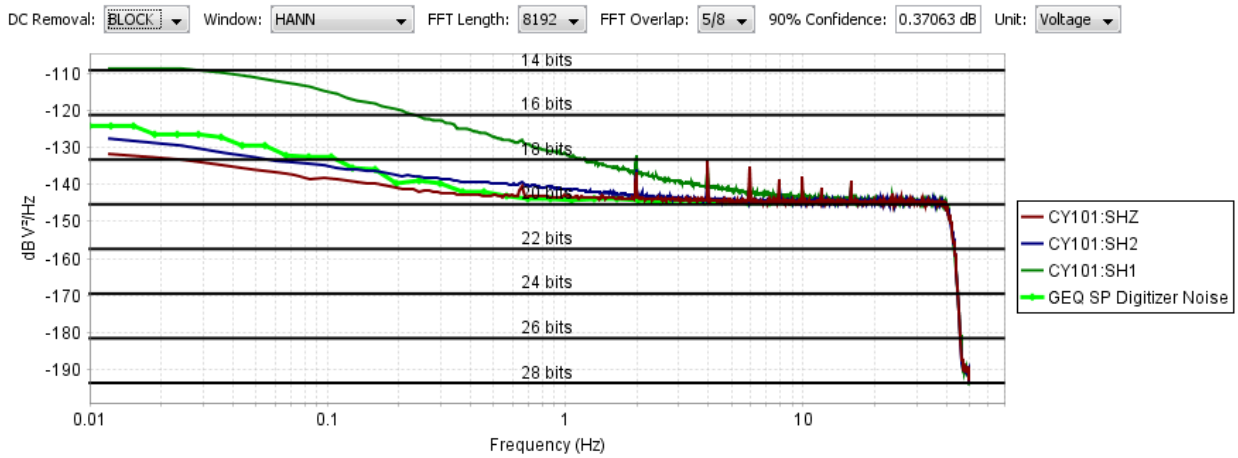


Figure 20 Digitizer #7 Elevated Noise Power Spectra on SH1

Based upon earlier investigation by Leidos into digitizer #5, the Cirrus Logic CS3301 chip on SH1 was replaced by Delta on August 23, 2016 and the digitizer was put back in the queue for testing.

Digitizer #7 was re-tested from August 25, 2016 to August 27, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on August 27, 2016.

4.1.8 Digitizer #8

Digitizer #8 was tested from July 8, 2016 to July 12, 2016 and found to have elevated input terminated noise on channels SHZ and SH2 that was significantly higher than expected or contained time-domain transients. Other than elevated noise, the digitizer performance was consistent with prior GEQ evaluations.

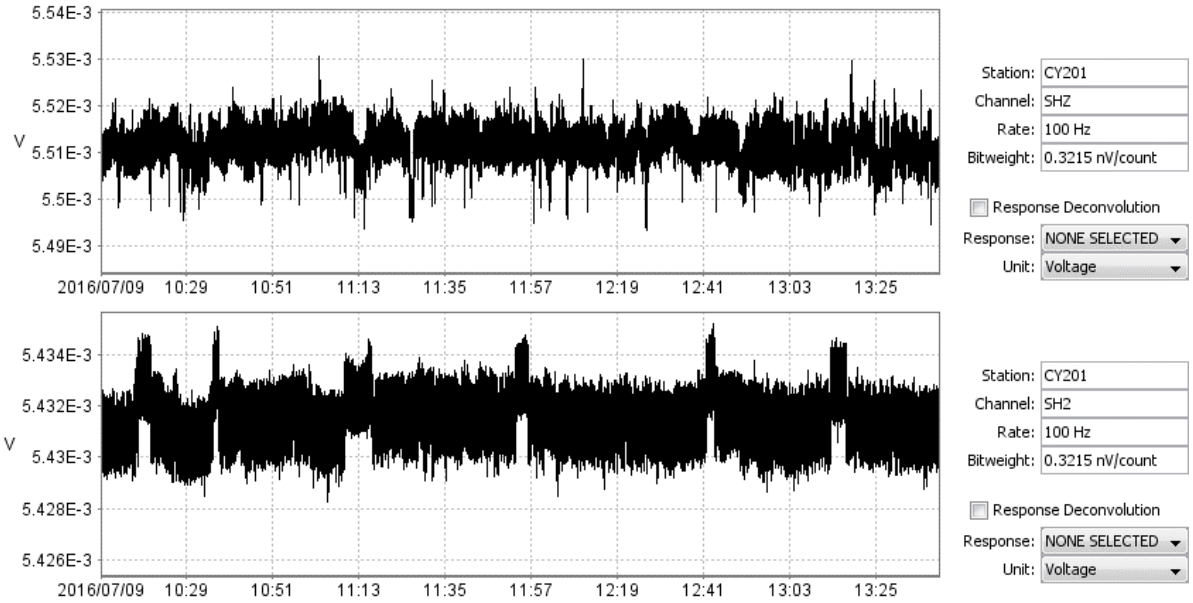


Figure 21 Digitizer #8 Elevated Noise Time Series on SHZ and SH2

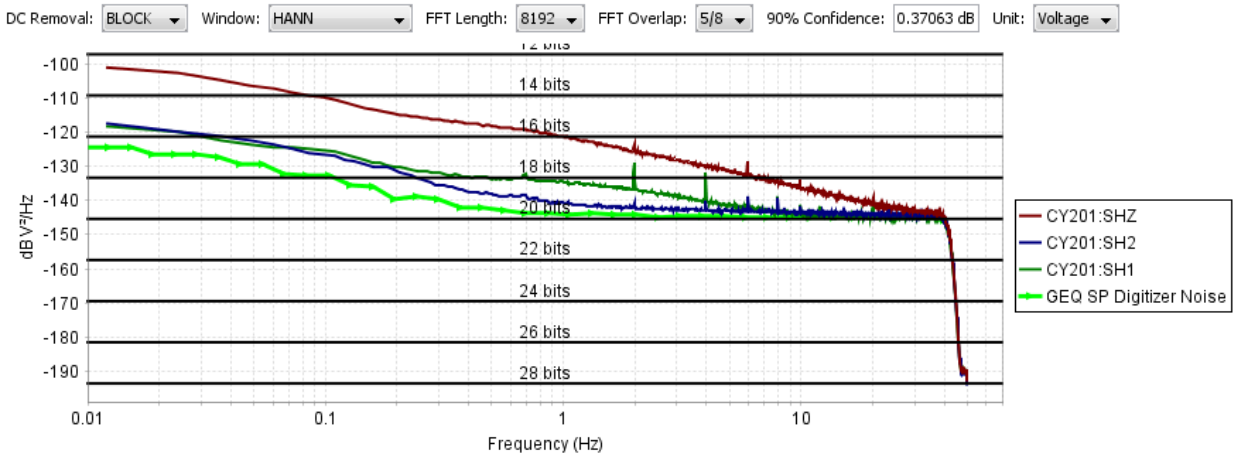


Figure 22 Digitizer #8 Elevated Noise Power Spectra on SHZ and SH2

Based upon earlier investigation by Leidos into digitizer #5, digitizer #8 was returned to the Delta team to have the Cirrus Logic CS3301 chips on SHZ and SH2 replaced.

Digitizer #8 was setup on September 2, 2016 to run input terminated noise. The noise levels were evaluated on September 6, 2016. It was found to still have elevated input terminated noise on channels SHZ consistent with the prior evaluation even though the CS3301 chip was replaced. Digitizer #8 was returned to the Delta team to have the CS3301 chip on SHZ replaced again.

Digitizer #8 was re-tested from Sept 6, 2016 to September 9, 2016 and found to have elevated input terminated noise on channel SHZ that was significantly higher than expected or contained time-domain transients. In addition, channel SHZ now exhibits a considerable low frequency DC offset that did not go away after having temperature stabilized. The terminated noise data was allowed to run for two overnight periods in order to verify that the low frequency noise would not settle out. The time-series and spectra plots of input-terminated noise below from the second overnight demonstrate what was observed. Other than elevated noise, the digitizer performance was consistent with prior GEQ evaluations.

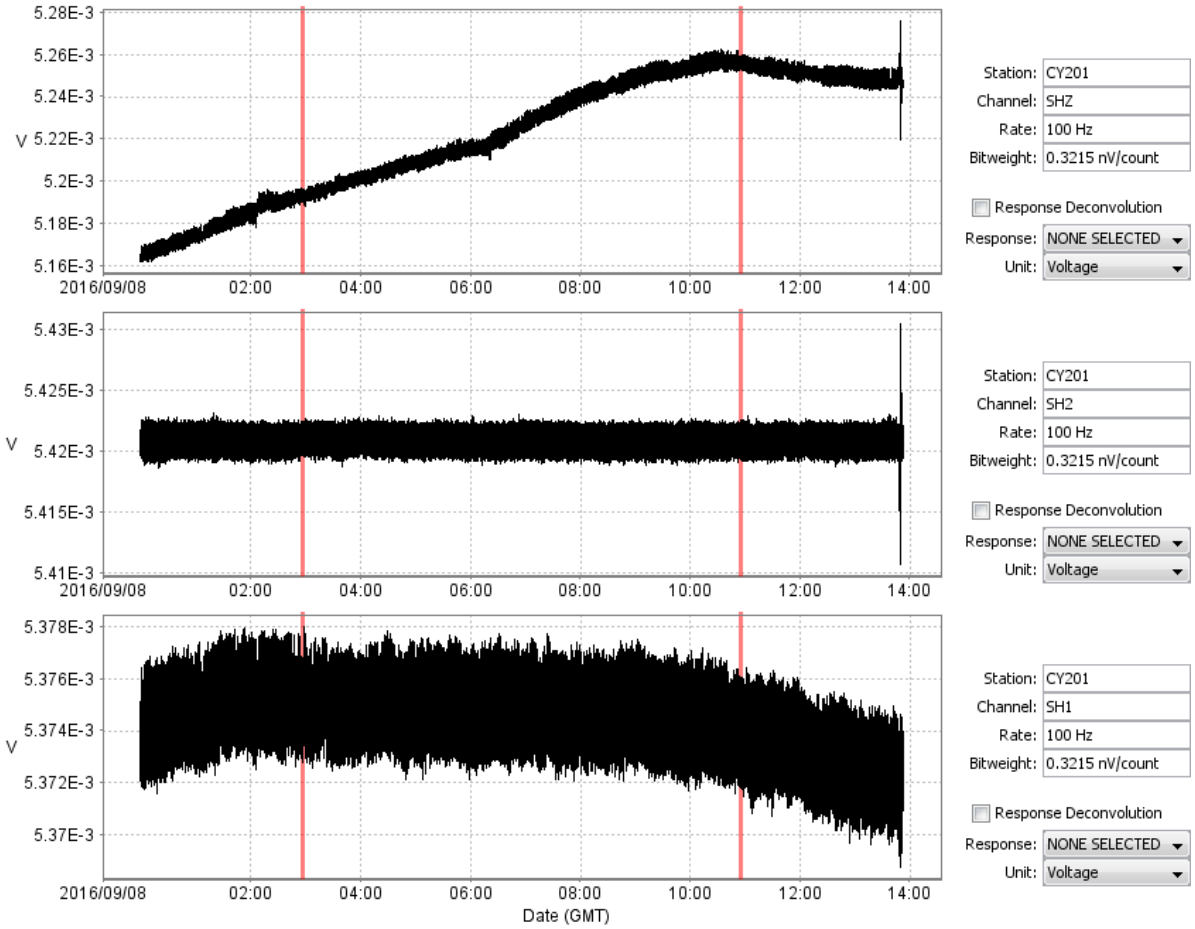


Figure 23 Digitizer #8 Elevated Noise Time Series on SHZ and SH2

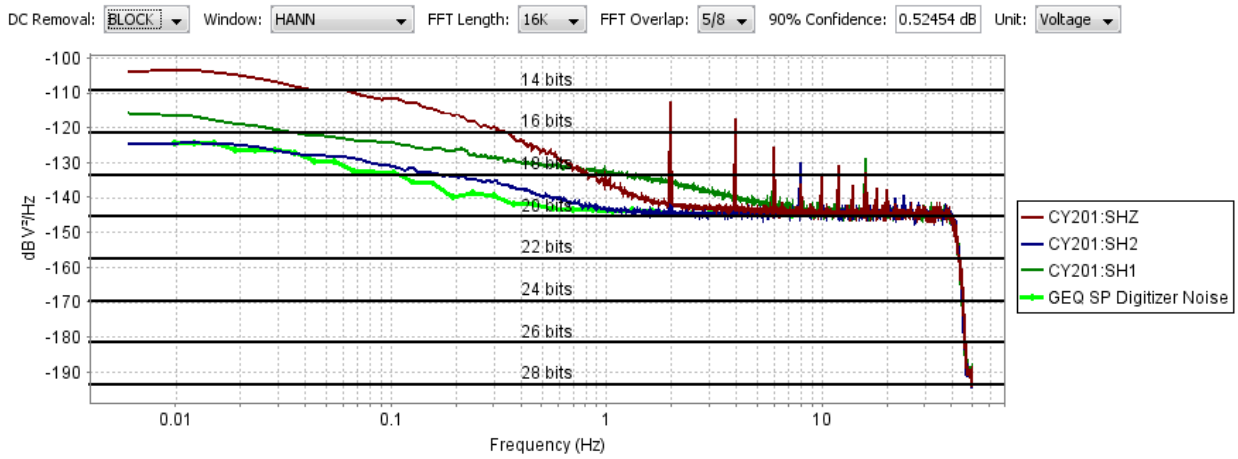


Figure 24 Digitizer #8 Elevated Noise Power Spectra on SHZ and SH2

Digitizer #8 was returned to the Leidos team for further investigation on September 9, 2016.

Digitizer #8 was re-tested from September 26, 2016 to September 27, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was observed that there was a slight amount of increased noise at frequencies below 0.0005 Hz. However, the amount of noise present was well outside the application passband and sufficiently low in amplitude to not be a concern.

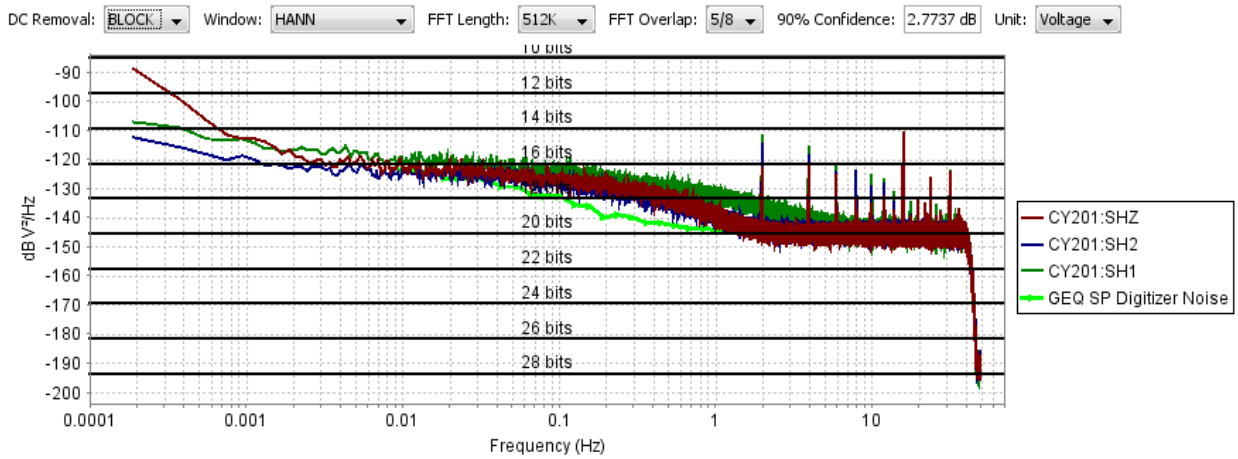


Figure 25 Digitizer #8 Elevated Noise Power Spectra on SHZ and SH2

Digitizer #8 was released to the Navy for integration on September 27, 2016.

4.1.9 Digitizer #9

Digitizer #9 was tested from July 8, 2016 to July 12, 2016 and found to have an inability to reliably communicate with the shore-side equipment. It was returned to the Leidos team for investigation in which it was determined that a combination of mechanical tolerances had resulted in a shorting of one of the negative power supply rails to ground. The affected power

supply was replaced in case of any potential damage and the digitizer was put back in the queue for testing.

Digitizer #9 was re-tested from August 18, 2016 to August 24, 2016 and found to have elevated input terminated noise on channels SH1 that was significantly higher than expected. Other than elevated noise, the digitizer performance was consistent with prior GEQ evaluations. However, towards the end of testing, it was noticed that optical signal power to the shore-side equipment was dropping unexpectedly.

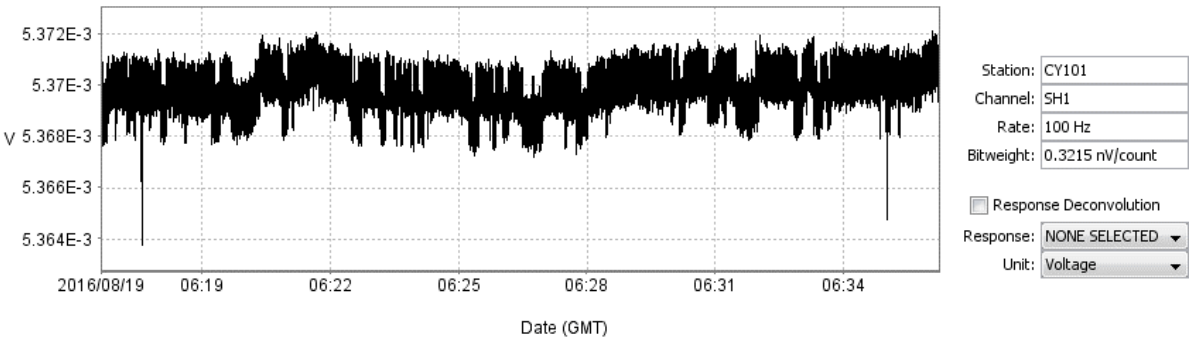


Figure 26 Digitizer #9 Elevated Noise Time Series on SH1

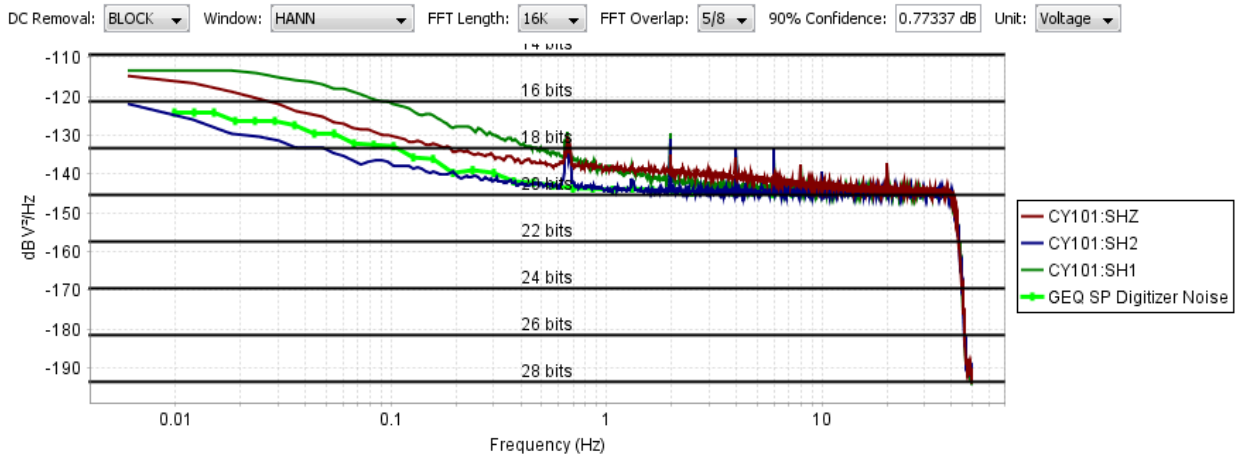


Figure 27 Digitizer #9 Elevated Noise Power Spectra on SH1

The digitizer was pulled off testing by the Leidos team for further investigation. In addition, digitizer #9 was returned to Delta to have the Cirrus Logic CS3301 chips on SH1 replaced.

Instead of replacing the CS3301 chips, the entire SDAQ board on #9 was replaced.
Digitizer #9, with the replaced SDAQ board, was tested from September 28, 2016 to September 30, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on September 30, 2016.

4.1.10 Digitizer #10

Digitizer #10 was tested from July 12, 2016 to July 14, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on July 14, 2016.

4.1.11 Digitizer #11

Digitizer #11 was tested from July 12, 2016 to July 14, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on July 14, 2016.

4.1.12 Digitizer #12

Digitizer #12 was tested from August 23, 2016 to August 25, 2016 and found to have performance that was consistent with the prior GEQ evaluations. Input-terminated noise was slightly elevated below 2 Hz on the broadband channels and has some higher frequency elevated noise on the short-period channels. However, there were no time-domain transients visible and so these channels were determined to be acceptable by the Air Force. It was released to the Navy for integration on August 25, 2016.

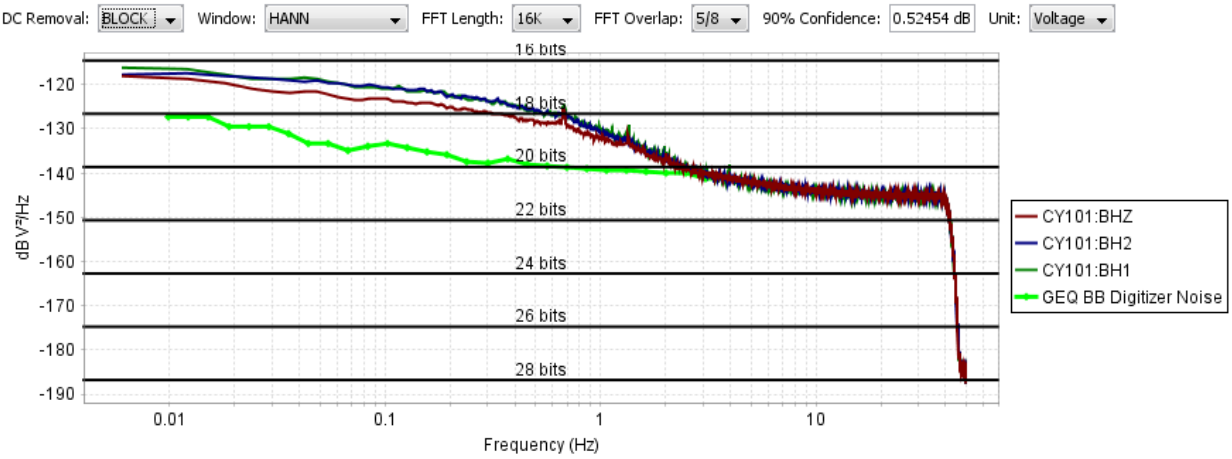


Figure 28 Digitizer #12 Noise Power Spectra on BHZ, BH2, and BH1

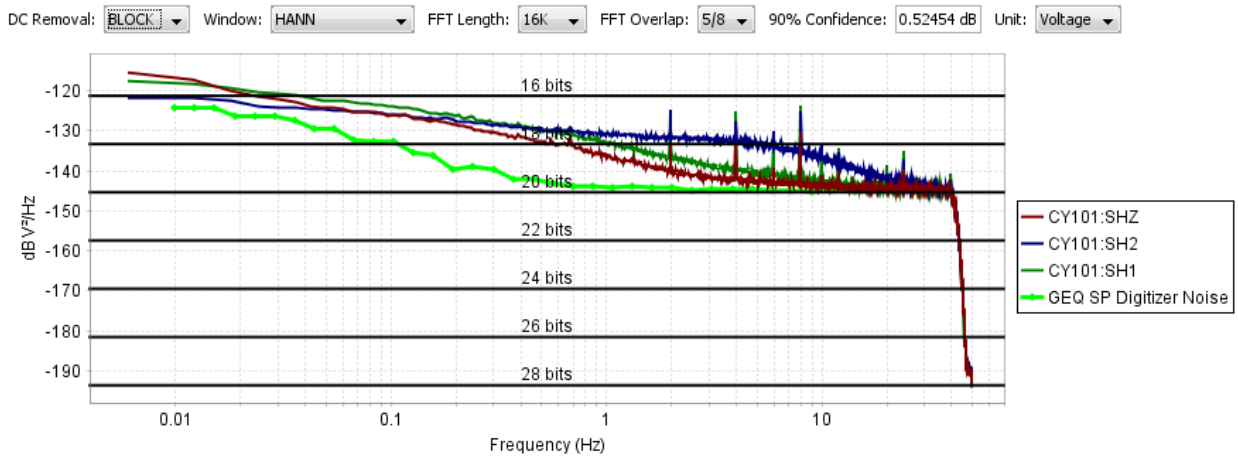


Figure 29 Digitizer #12 Noise Power Spectra on SHZ, SH2, and SH1

4.1.13 Digitizer #13

Digitizer #13 was tested from August 15, 2016 to August 16, 2016 and found to have elevated input terminated noise on channel SH2 that was significantly higher than expected. No other evaluation of digitizer performance was performed other than input-terminated noise.

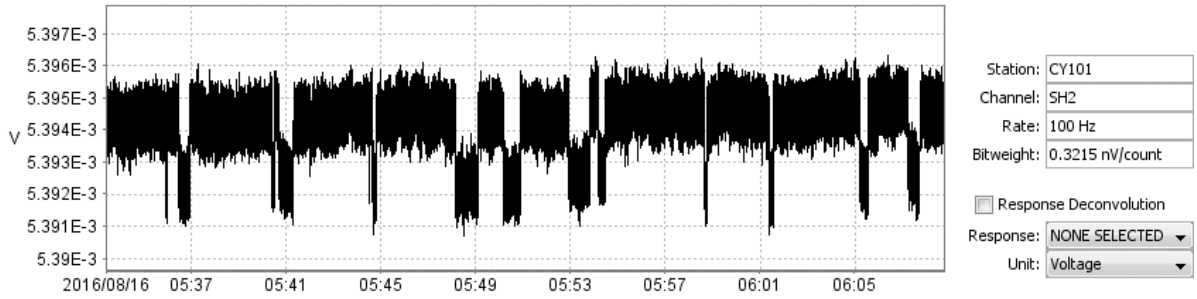


Figure 30 Digitizer #13 Elevated Noise Time Series on SH2

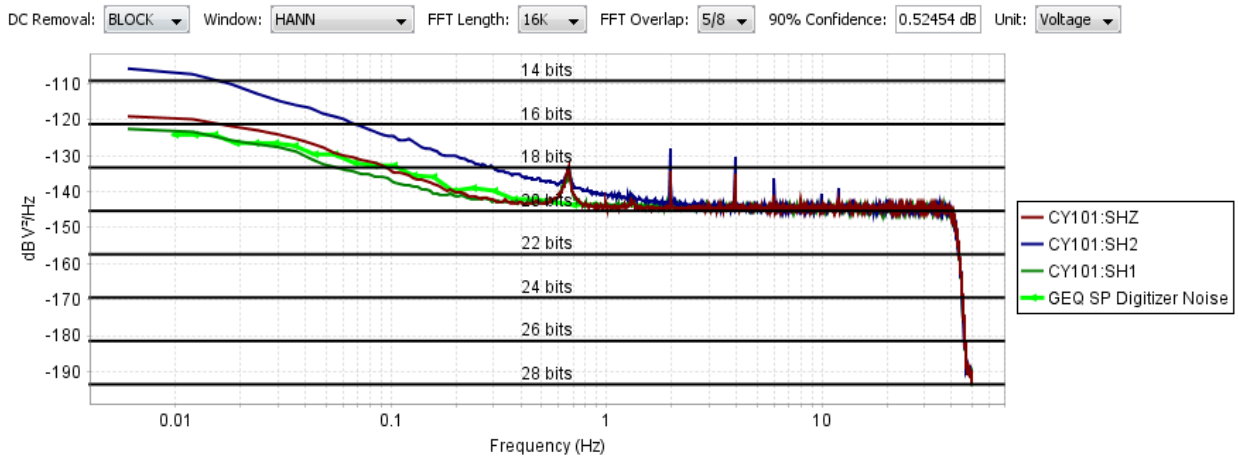


Figure 31 Digitizer #13 Elevated Noise Power Spectra on SH2

Based upon earlier investigation by Leidos into digitizer #5, the Cirrus Logic CS3301 chip on SH2 was replaced and the digitizer was put back in the queue for testing.

Digitizer #13 was setup on September 2, 2016 to run input terminated noise. The noise levels were evaluated on September 6, 2016. It was found that on SH2, the channel that the CS3301 was replaced on, now has a significant cyclical variant in its DC offset with an approximate 3-hour period.

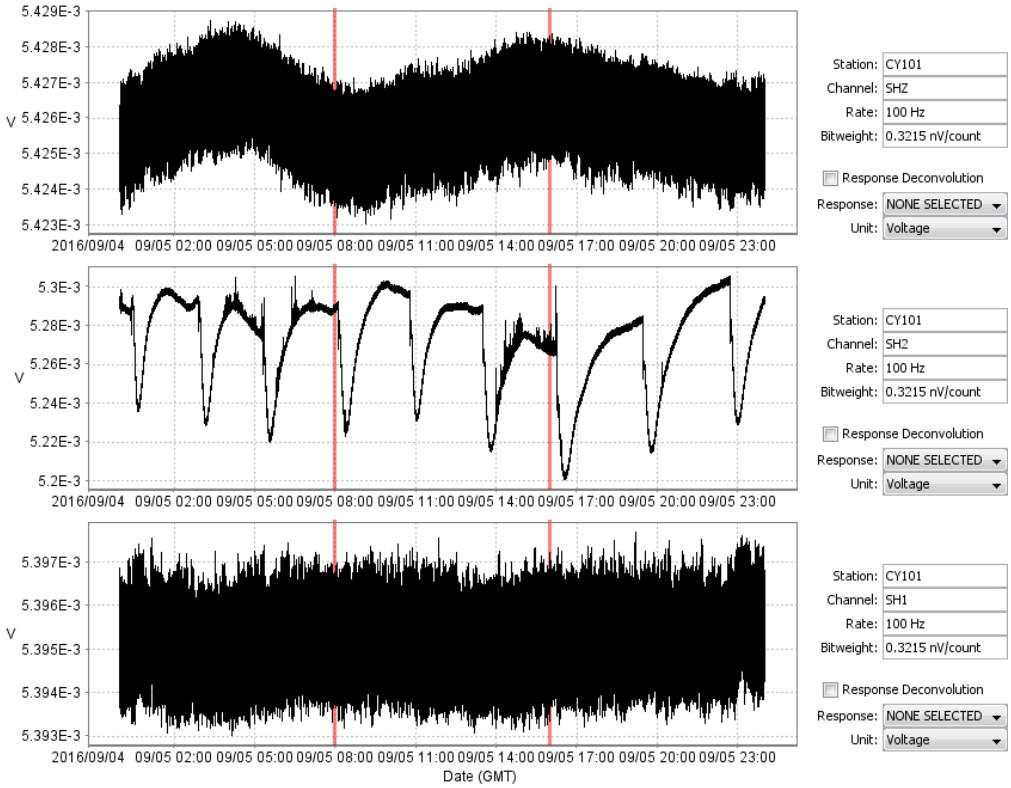


Figure 32 Digitizer #13 Cyclical DC offset on SH2

Digitizer #13 was pulled from testing by the Leidos team for further investigation. The CS3301 on SH2 was re-replaced with greater attention to detail when removing the conformal coating and cleaning of the board before mounting the chip.

Digitizer #13 was re-tested from September 19, 2016 to September 20, 2016 and found to have performance that was consistent with the prior GEQ evaluations. Input-terminated noise was slightly elevated below 0.5 Hz on the broadband channels, however not excessively so. It was released to the Navy for integration on September 20, 2016.

4.1.14 Digitizer #14

Digitizer #14 was tested from August 15, 2016 to August 18, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on August 18, 2016.

4.1.15 Digitizer #15

Digitizer #15 was tested from August 16, 2016 to August 18, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on August 18, 2016.

4.1.16 Digitizer #16

Digitizer #16 was tested from August 18, 2016 to August 23, 2016 and found to have performance that was consistent with the prior GEQ evaluations. It was released to the Navy for integration on August 23, 2016.

4.1.17 Digitizer #17

Digitizer #17 was tested from August 20, 2016 to August 23, 2016 and found to have performance that was consistent with the prior GEQ evaluations. Input-terminated noise was slightly elevated below 2 Hz on the broadband channels and has some higher frequency elevated noise on the short-period channels. However, the noise remains well below the expected site-noise and there were no time-domain transients visible and so these channels were determined to be acceptable by the Air Force.

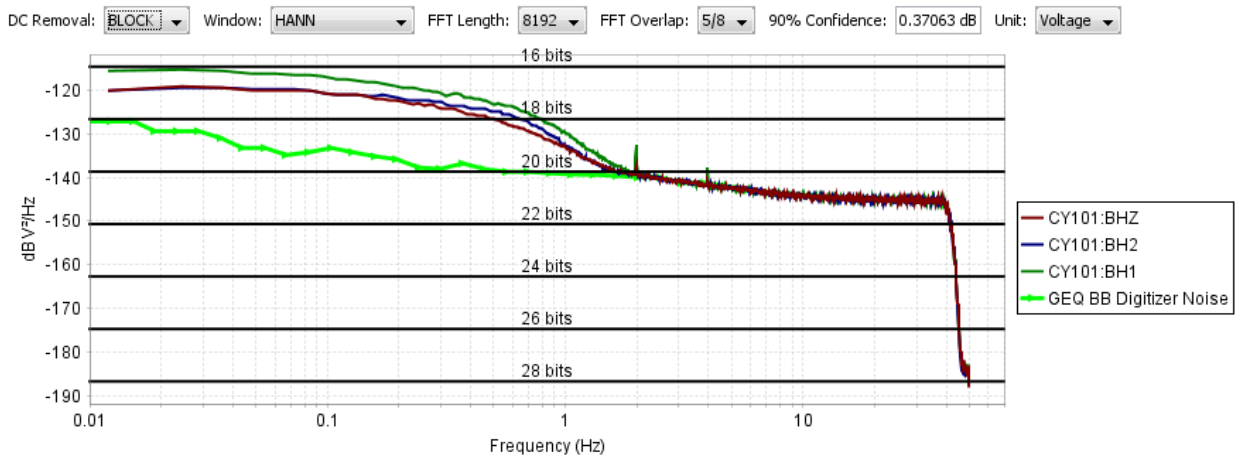


Figure 33 Digitizer #17 Noise Power Spectra on BHZ, BH2, and BH1

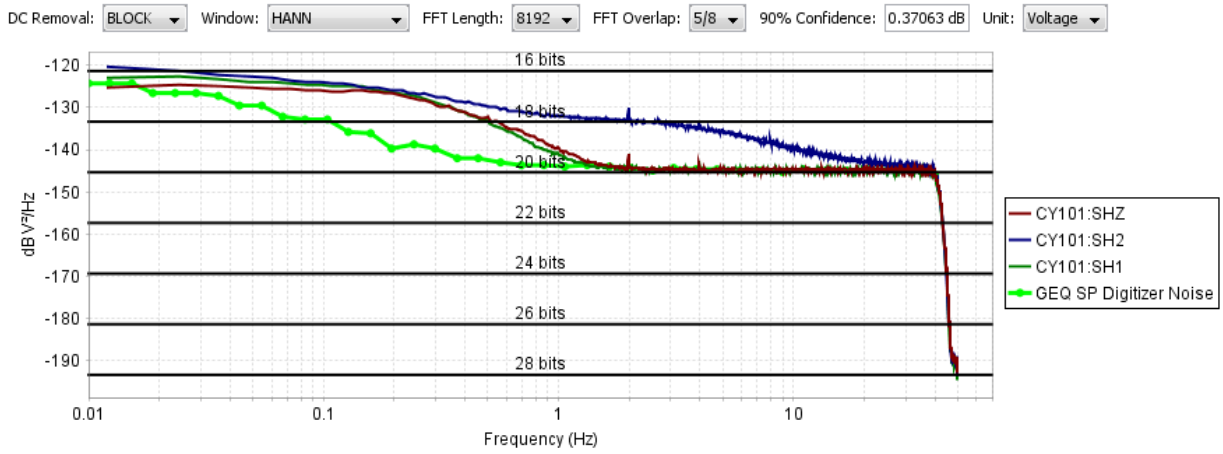


Figure 34 Digitizer #17 Noise Power Spectra on SHZ, SH2, and SH1

Digitizer #17 did exhibit an inability to output the calibration signal on the Nanometrics cable. The digitizer was returned to the Leidos team for investigation who determined that the calibration lines on the cable port on the digitizer had been mis-wired. The digitizer was returned to Delta for correction and the digitizer was put back in the queue for testing.

Digitizer #17 was re-tested from September 6, 2016 to September 9, 2016 and found to have performance that was consistent with the prior GEQ evaluations. Input-terminated noise was consistent with the prior evaluation. The calibration line is now working properly. It was released to the Navy for integration on September 9, 2016

4.1.18 Digitizer #18

Digitizer #18 was tested from August 23, 2016 to August 25, 2016 and found to have performance that was consistent with the prior GEQ evaluations. Input-terminated noise was slightly elevated below 1Hz on the broadband channels. However, the noise remains well below the expected site-noise and there were no time-domain transients visible and so these channels were determined to be acceptable by the Air Force. It was released to the Navy for integration on August 25, 2016.

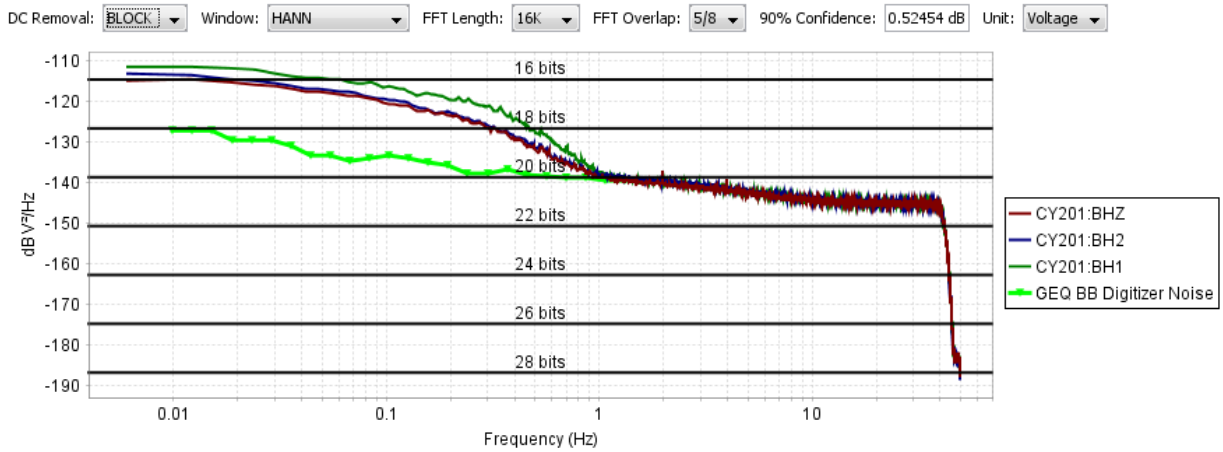


Figure 35 Digitizer #18 Noise Power Spectra on BHZ, BH2, and BH1

4.2 Input Impedance

The digitizer input channel DC impedance was measured using the calibrated meter Agilent 3458A #MY45044336. A break-out connection was made at the test station that bypassed the test stations rotary switches. Signals were carried from the breakout box to the reference meter using a pair of 50 ohm BNC cables.

For each of the sets of broadband and short-period channels, all three channels were tied together prior to measuring the channel impedance. The purpose of the measurement was to verify that there was no impedance issue when utilizing the signal generator. It is expected that these values do not reflect the impedances of the individual channels.

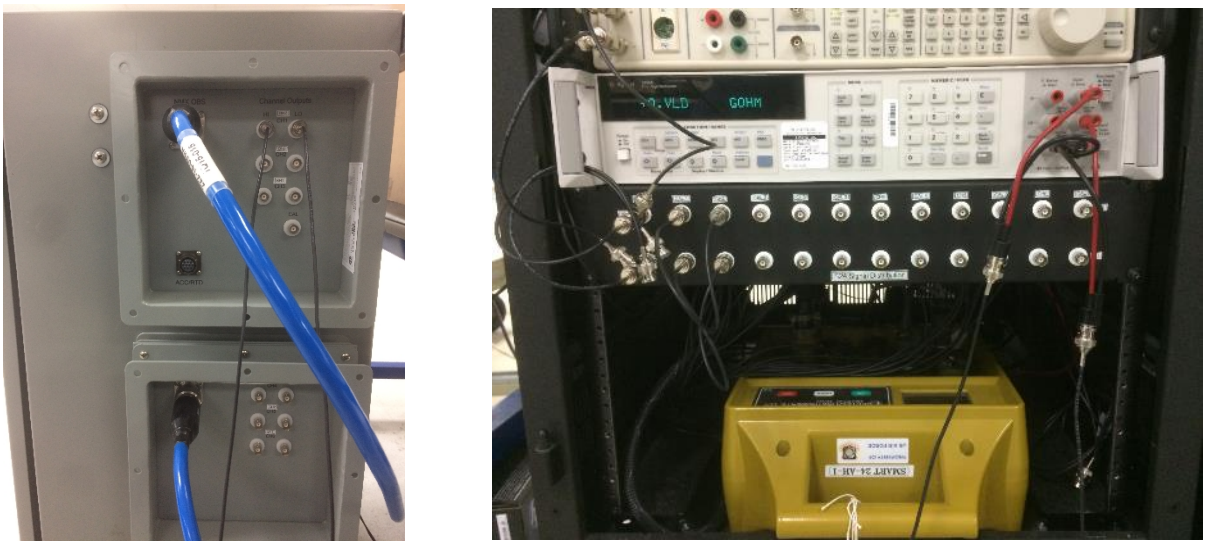


Figure 36 Input Impedance measurement configuration

The measured impedance was allowed to settle before a measurement from the meter was recorded. Two significant digits are reported.

Table 6 Input Impedance Values

Digitizer	Broadband	Short-period
# 1	Gohm	3.5 Mohm
# 2	0.35 Gohm	3.5 Mohm
# 3	0.98 Gohm	3.5 Mohm
# 4	Gohm	3.6 Mohm
# 5	Gohm	3.5 Mohm
# 6	Gohm	3.6 Mohm
# 7	Gohm	3.4 Mohm
# 8	Gohm	3.5 Mohm
# 9	Gohm	3.4 Mohm
# 10	1.0 Gohm	3.5 Mohm
# 11	0.97 Gohm	3.5 Mohm
# 12	Gohm	3.3 Mohm
# 13	Gohm	3.5 Mohm
# 14	0.75 Gohm	3.5 Mohm
# 15	Gohm	3.5 Mohm
# 16	Gohm	3.9 Mohm
# 17	Gohm	3.4 Mohm
# 18	Gohm	3.6 Mohm

Note that for the broadband channels which recorded “Gohm”, the impedance was high enough that the reference meter was unable to make a measurement and simply indicated an open circuit.

4.3 Sensitivity

The sensitivity of each digitizer input channel was measured relative to the calibrated meter Agilent 3458A #MY45044336. Two sensitivity values were estimated on the broadband channels. The first was using a 10 Hz sinusoid with amplitude equal to 10% of the channels nominal full scale value. The second was using a 10 Hz sinusoid with amplitude equal to 50% of the channels nominal full scale value. A sinusoid was used for sensitivity measurements due to the broadband channels having a preamplifier with a high-pass filter with a corner at 3.2 Hz that would filter out DC signals.

The recording on the meter was performed at 500 Hz in order to minimize the effects of the meter's high frequency roll-off. Recording a 10 Hz signal at 500 Hz with the meter in DC mode was previously determined to have a less than 0.02% difference in the amplitude when compared to a measuring a DC signal.

On the short period channels, a 10% amplitude DC sensitivity was determined in addition to the 10% and 50% sinusoid sensitivities.

The sinusoid amplitudes were determined by applying a least-squared sine fit to 50 seconds (500 cycles) of data from the recordings on both the SHDAS digitizer and the reference meter. No other filtering or processing of the data was performed.

The DC amplitudes were determined by computing an average over 20 seconds of data from the positive 10% and negative 10% amplitude signals.

The sensitivities were then calculated by computing the ratio between the reference meter amplitude in volts divided by the digitizer channel amplitude in counts. Sensitivities across repeated measurements were stable to within 3 digits of precision. All sensitivity values shown have 4 digits of precision with the understanding that they are only repeatable to within 0.1 %.

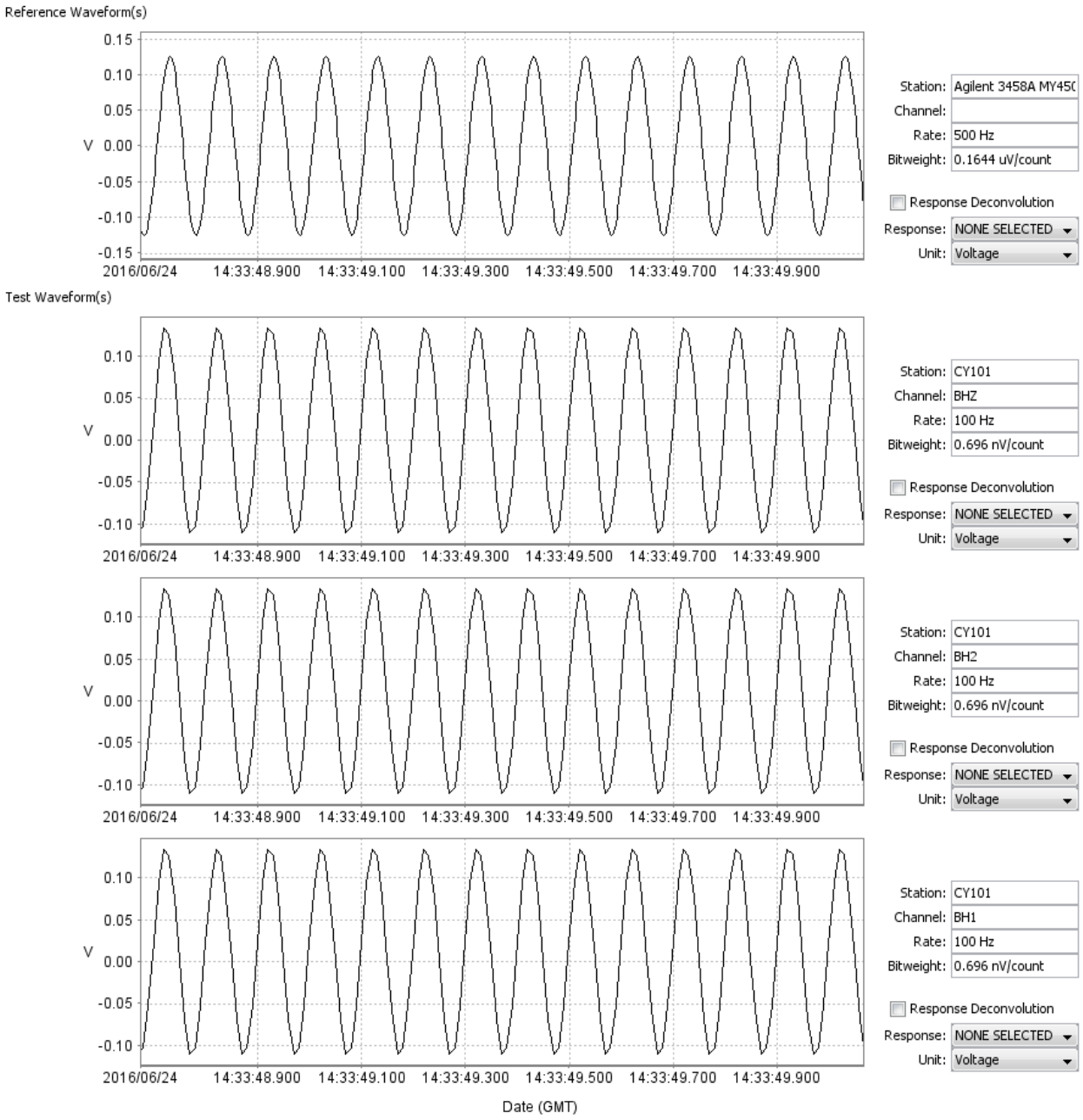


Figure 37 Small Signal 10 Hz Sensitivity

Table 7 Small Signal 10 Hz Sensitivity

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
#1	0.6969 nV/cnt	0.6986 nV/cnt	0.6984 nV/cnt	0.3201 nV/cnt	0.3217 nV/cnt	0.3213 nV/cnt
# 2	0.6960 nV/cnt	0.6956 nV/cnt	0.6960 nV/cnt	0.3204 nV/cnt	0.3209 nV/cnt	0.3204 nV/cnt
# 3	0.6954 nV/cnt	0.6953 nV/cnt	0.6946 nV/cnt	0.3199 nV/cnt	0.3202 nV/cnt	0.3209 nV/cnt
# 4	0.6964 nV/cnt	0.6980 nV/cnt	0.6976 nV/cnt	0.3208 nV/cnt	0.3198 nV/cnt	0.3207 nV/cnt
# 5	0.6980 nV/cnt	0.6982 nV/cnt	0.6982 nV/cnt	0.3199 nV/cnt	0.3214 nV/cnt	0.3202 nV/cnt
# 6	0.6974 nV/cnt	0.6979 nV/cnt	0.6988 nV/cnt	0.3200 nV/cnt	0.3206 nV/cnt	0.3202 nV/cnt
# 7	0.6969 nV/cnt	0.6973 nV/cnt	0.6979 nV/cnt	0.3202 nV/cnt	0.3201 nV/cnt	0.3207 nV/cnt
# 8	0.6967 nV/cnt	0.6957 nV/cnt	0.6986 nV/cnt	0.3210 nV/cnt	0.3203 nV/cnt	0.3196 nV/cnt
# 9	0.6959 nV/cnt	0.6978 nV/cnt	0.6959 nV/cnt	0.3205 nV/cnt	0.3204 nV/cnt	0.3197 nV/cnt
# 10	0.6980 nV/cnt	0.6972 nV/cnt	0.6986 nV/cnt	0.3200 nV/cnt	0.3206 nV/cnt	0.3200 nV/cnt
# 11	0.6990 nV/cnt	0.6962 nV/cnt	0.6970 nV/cnt	0.3200 nV/cnt	0.3199 nV/cnt	0.3197 nV/cnt
# 12	0.6966 nV/cnt	0.6971 nV/cnt	0.6989 nV/cnt	0.3206 nV/cnt	0.3202 nV/cnt	0.3204 nV/cnt
# 13	0.6976 nV/cnt	0.6965 nV/cnt	0.6995 nV/cnt	0.3204 nV/cnt	0.3200 nV/cnt	0.3206 nV/cnt
# 14	0.6984 nV/cnt	0.6967 nV/cnt	0.6990 nV/cnt	0.3207 nV/cnt	0.3203 nV/cnt	0.3208 nV/cnt
# 15	0.6986 nV/cnt	0.6966 nV/cnt	0.6958 nV/cnt	0.3208 nV/cnt	0.3202 nV/cnt	0.3207 nV/cnt
# 16	0.6955 nV/cnt	0.6958 nV/cnt	0.6962 nV/cnt	0.3213 nV/cnt	0.3202 nV/cnt	0.3202 nV/cnt
# 17	0.6949 nV/cnt	0.6958 nV/cnt	0.6952 nV/cnt	0.3199 nV/cnt	0.3195 nV/cnt	0.3201 nV/cnt
# 18	0.6972 nV/cnt	0.6973 nV/cnt	0.6960 nV/cnt	0.3201 nV/cnt	0.3197 nV/cnt	0.3196 nV/cnt

Table 8 Large Signal 10 Hz Sensitivity

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
#1	0.6969 nV/cnt	0.6986 nV/cnt	0.6984 nV/cnt	0.3201 nV/cnt	0.3217 nV/cnt	0.3213 nV/cnt
# 2	0.6960 nV/cnt	0.6956 nV/cnt	0.6960 nV/cnt	0.3204 nV/cnt	0.3209 nV/cnt	0.3204 nV/cnt
# 3	0.6954 nV/cnt	0.6953 nV/cnt	0.6946 nV/cnt	0.3199 nV/cnt	0.3202 nV/cnt	0.3209 nV/cnt
# 4	0.6964 nV/cnt	0.6980 nV/cnt	0.6976 nV/cnt	0.3208 nV/cnt	0.3198 nV/cnt	0.3207 nV/cnt
# 5	0.6980 nV/cnt	0.6982 nV/cnt	0.6982 nV/cnt	0.3199 nV/cnt	0.3214 nV/cnt	0.3202 nV/cnt
# 6	0.6974 nV/cnt	0.6979 nV/cnt	0.6988 nV/cnt	0.3200 nV/cnt	0.3206 nV/cnt	0.3202 nV/cnt
# 7	0.6969 nV/cnt	0.6973 nV/cnt	0.6979 nV/cnt	0.3202 nV/cnt	0.3201 nV/cnt	0.3207 nV/cnt
# 8	0.6967 nV/cnt	0.6957 nV/cnt	0.6985 nV/cnt	0.3210 nV/cnt	0.3203 nV/cnt	0.3196 nV/cnt
# 9	0.6959 nV/cnt	0.6978 nV/cnt	0.6959 nV/cnt	0.3205 nV/cnt	0.3204 nV/cnt	0.3197 nV/cnt
# 10	0.6980 nV/cnt	0.6972 nV/cnt	0.6986 nV/cnt	0.3200 nV/cnt	0.3206 nV/cnt	0.3200 nV/cnt
# 11	0.6990 nV/cnt	0.6962 nV/cnt	0.6970 nV/cnt	0.3200 nV/cnt	0.3199 nV/cnt	0.3197 nV/cnt
# 12	0.6966 nV/cnt	0.6971 nV/cnt	0.6988 nV/cnt	0.3206 nV/cnt	0.3202 nV/cnt	0.3204 nV/cnt
# 13	0.6976 nV/cnt	0.6965 nV/cnt	0.6995 nV/cnt	0.3204 nV/cnt	0.3200 nV/cnt	0.3206 nV/cnt
# 14	0.6984 nV/cnt	0.6967 nV/cnt	0.6990 nV/cnt	0.3207 nV/cnt	0.3203 nV/cnt	0.3208 nV/cnt
# 15	0.6986 nV/cnt	0.6966 nV/cnt	0.6958 nV/cnt	0.3208 nV/cnt	0.3202 nV/cnt	0.3207 nV/cnt
# 16	0.6955 nV/cnt	0.6958 nV/cnt	0.6962 nV/cnt	0.3213 nV/cnt	0.3202 nV/cnt	0.3202 nV/cnt
# 17	0.6949 nV/cnt	0.6958 nV/cnt	0.6952 nV/cnt	0.3199 nV/cnt	0.3195 nV/cnt	0.3201 nV/cnt
# 18	0.6972 nV/cnt	0.6973 nV/cnt	0.6960 nV/cnt	0.3201 nV/cnt	0.3196 nV/cnt	0.3196 nV/cnt

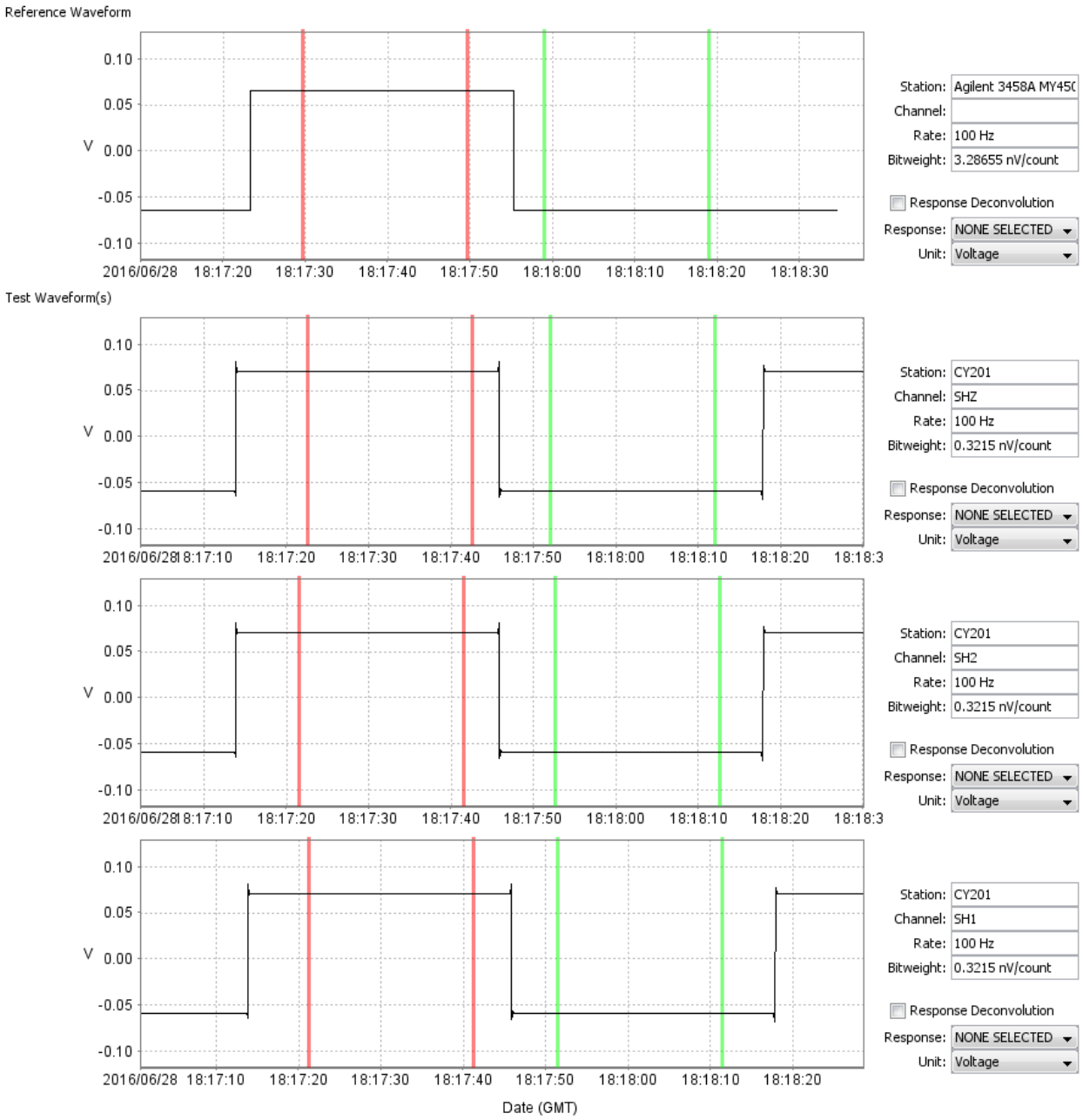


Figure 38 DC Sensitivity

Table 9 Small Signal DC Sensitivity

Digitizer	SHZ	SH2	SH1
#1	0.3200 nV/cnt	0.3217 nV/cnt	0.3212 nV/cnt
# 2	0.3204 nV/cnt	0.3209 nV/cnt	0.3203 nV/cnt
# 3	0.3199 nV/cnt	0.3202 nV/cnt	0.3208 nV/cnt
# 4	0.3207 nV/cnt	0.3197 nV/cnt	0.3207 nV/cnt
# 5	0.3198 nV/cnt	0.3214 nV/cnt	0.3202 nV/cnt
# 6	0.3199 nV/cnt	0.3206 nV/cnt	0.3202 nV/cnt
# 7	0.3202 nV/cnt	0.3200 nV/cnt	0.3206 nV/cnt
# 8	0.3202 nV/cnt	0.3203 nV/cnt	0.3195 nV/cnt
# 9	0.3204 nV/cnt	0.3203 nV/cnt	0.3197 nV/cnt
# 10	0.3199 nV/cnt	0.3205 nV/cnt	0.3199 nV/cnt
# 11	0.3200 nV/cnt	0.3198 nV/cnt	0.3197 nV/cnt
# 12	0.3205 nV/cnt	0.3201 nV/cnt	0.3203 nV/cnt
# 13	0.3203 nV/cnt	0.3199 nV/cnt	0.3205 nV/cnt
# 14	0.3207 nV/cnt	0.3203 nV/cnt	0.3207 nV/cnt
# 15	0.3207 nV/cnt	0.3201 nV/cnt	0.3207 nV/cnt
# 16	0.3213 nV/cnt	0.3202 nV/cnt	0.3201 nV/cnt
# 17	0.3198 nV/cnt	0.3195 nV/cnt	0.3200 nV/cnt
# 18	0.3201 nV/cnt	0.3196 nV/cnt	0.3196 nV/cnt

4.4 DC Offset

The DC offset of each digitizer input channel was verified using the data collected from the evaluation of Terminated Noise and Full Scale. The bit-weights obtained from the small-signal 10 Hz sensitivity results in Table 7 were used to convert the data from counts to volts for each channel.

On the terminated noise data, an average value was computed over the time period of data used for evaluating the digitizer self-noise.

Table 10 Terminated Noise DC Offsets

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
#1	11.7481 mV	11.7110 mV	11.7313 mV	5.4063 mV	5.4232 mV	5.3839 mV
# 2	11.6637 mV	11.7482 mV	11.7361 mV	5.3596 mV	5.3912 mV	5.4250 mV
# 3	11.7023 mV	11.7021 mV	11.6316 mV	5.3848 mV	5.3577 mV	5.3752 mV
# 4	11.8268 mV	11.7795 mV	11.7640 mV	5.3559 mV	5.3518 mV	5.3801 mV
# 5	11.8014 mV	11.8043 mV	11.7248 mV	5.3402 mV	5.4132 mV	5.4297 mV
# 6	11.7127 mV	11.7327 mV	11.7283 mV	5.4120 mV	5.3805 mV	5.3645 mV
# 7	11.7693 mV	11.7134 mV	11.6935 mV	5.3816 mV	5.3712 mV	5.7528 mV
# 8	11.6544 mV	11.7529 mV	11.7006 mV	5.3522 mV	5.4041 mV	5.3501 mV
# 9	11.7933 mV	11.7647 mV	11.6930 mV	5.4453 mV	5.3674 mV	5.3330 mV
# 10	11.6821 mV	11.7175 mV	11.7413 mV	5.3779 mV	5.3779 mV	5.3995 mV
# 11	11.7210 mV	11.6028 mV	11.7244 mV	5.3996 mV	5.4090 mV	5.3813 mV
# 12	11.7729 mV	11.7380 mV	11.7497 mV	5.3925 mV	5.3783 mV	5.3675 mV
# 13	11.7371 mV	11.7963 mV	11.7539 mV	5.4032 mV	5.3694 mV	5.3797 mV
# 14	11.8145 mV	11.6587 mV	11.7775 mV	5.3754 mV	5.4046 mV	5.3758 mV
# 15	11.6719 mV	11.7531 mV	11.7860 mV	5.3953 mV	5.4120 mV	5.3766 mV
# 16	11.6292 mV	11.6647 mV	11.6435 mV	5.4292 mV	5.4065 mV	5.4114 mV
# 17	11.7607 mV	11.7338 mV	11.7149 mV	5.3768 mV	5.3877 mV	5.3380 mV
# 18	11.7865 mV	11.7428 mV	11.7179 mV	5.4122 mV	5.3783 mV	5.3614 mV

On the full scale data, a four-parameter (amplitude, frequency, phase, and dc-offset) sinusoidal least-squared fit was performed to each of the sequences. The resulting DC-offset is reported here. Although the DC-offsets measured during the various evaluations of sensitivity (large signal AC, small signal AC, and DC) are not reported in this document, they were compared and all found to be within less than 1 % of one another.

Table 11 Full Scale DC Offsets

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
#1	11.7320 mV	11.6894 mV	11.7169 mV	4.4492 mV	4.4880 mV	4.4483 mV
# 2	11.6531 mV	11.7359 mV	11.7231 mV	4.4390 mV	4.3919 mV	4.3729 mV
# 3	11.6864 mV	11.6830 mV	11.6125 mV	4.4264 mV	4.4019 mV	4.4333 mV
# 4	11.8101 mV	11.7629 mV	11.7500 mV	4.4140 mV	4.4022 mV	4.4283 mV
# 5	11.7628 mV	11.7692 mV	11.6902 mV	4.4023 mV	4.4692 mV	4.4833 mV
# 6	11.6949 mV	11.7157 mV	11.7128 mV	4.4529 mV	4.4454 mV	4.4167 mV
# 7	11.7543 mV	11.6969 mV	11.6748 mV	4.4661 mV	4.4516 mV	4.4767 mV
# 8	11.6506 mV	11.7021 mV	11.7272 mV	4.4751 mV	4.4519 mV	4.4203 mV
# 9	11.7757 mV	11.7468 mV	11.6766 mV	4.4937 mV	4.4133 mV	4.4133 mV
# 10	11.6650 mV	11.7017 mV	11.7263 mV	4.4746 mV	4.4845 mV	4.4977 mV
# 11	11.7047 mV	11.5866 mV	11.7076 mV	4.4993 mV	4.4890 mV	4.4873 mV
# 12	11.7576 mV	11.7196 mV	11.7308 mV	4.4681 mV	4.4486 mV	4.4331 mV
# 13	11.7197 mV	11.7791 mV	11.7344 mV	4.4727 mV	4.4377 mV	4.4454 mV
# 14	11.7966 mV	11.6428 mV	11.7630 mV	4.4334 mV	4.4507 mV	4.4498 mV
# 15	11.6466 mV	11.7306 mV	11.7657 mV	4.4548 mV	4.4731 mV	4.4291 mV
# 16	11.6119 mV	11.6475 mV	11.6288 mV	4.5095 mV	4.4801 mV	4.4895 mV
# 17	11.7433 mV	11.7194 mV	11.6974 mV	4.4406 mV	4.4512 mV	4.3972 mV
# 18	11.7713 mV	11.7271 mV	11.6970 mV	4.5089 mV	4.4658 mV	4.4350 mV

4.5 Full Scale

The full scale of each digitizer input channel was verified using an injected 10 Hz signal from the SRS DS360 with amplitude equal to the digitizer's nominal full scale. The peak of the signal was observed to verify that no clipping or flattening of the sinusoid was observed.

The bit-weights obtained from the small-signal 10 Hz sensitivity results in Table 7 were used to convert the data from counts to volts for each channel.

The nominal full scale for the broadband channels (BHZ, BH2, and BH1) is 2.8 Vpp. The nominal full scale for the short-period channels (SHZ, SH2, and SH1) is 1.3 Vpp.

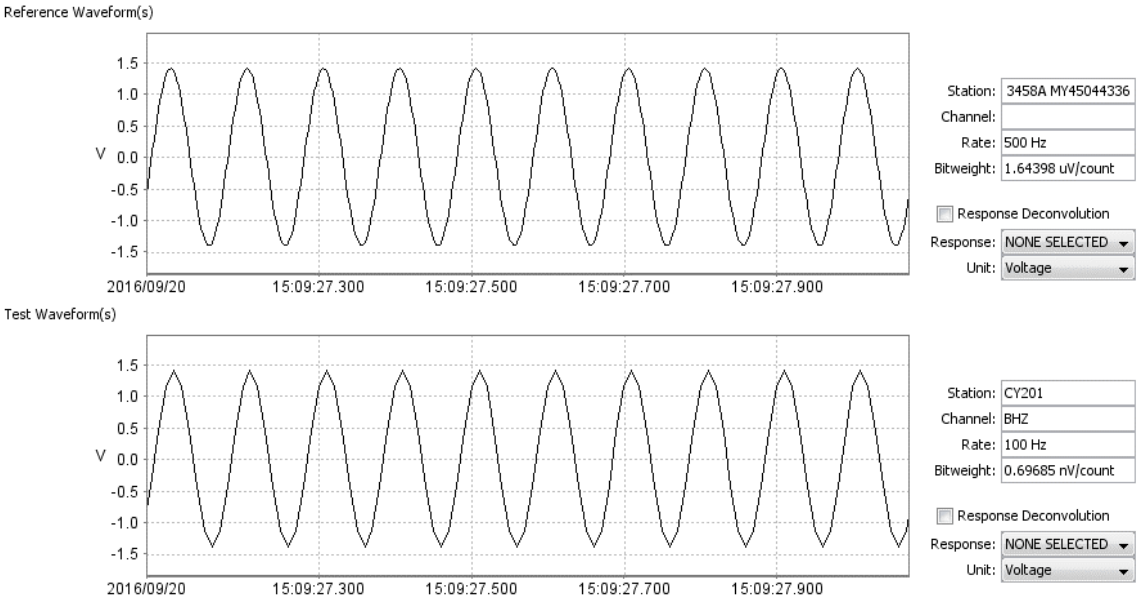


Figure 39 Broadband Full Scale

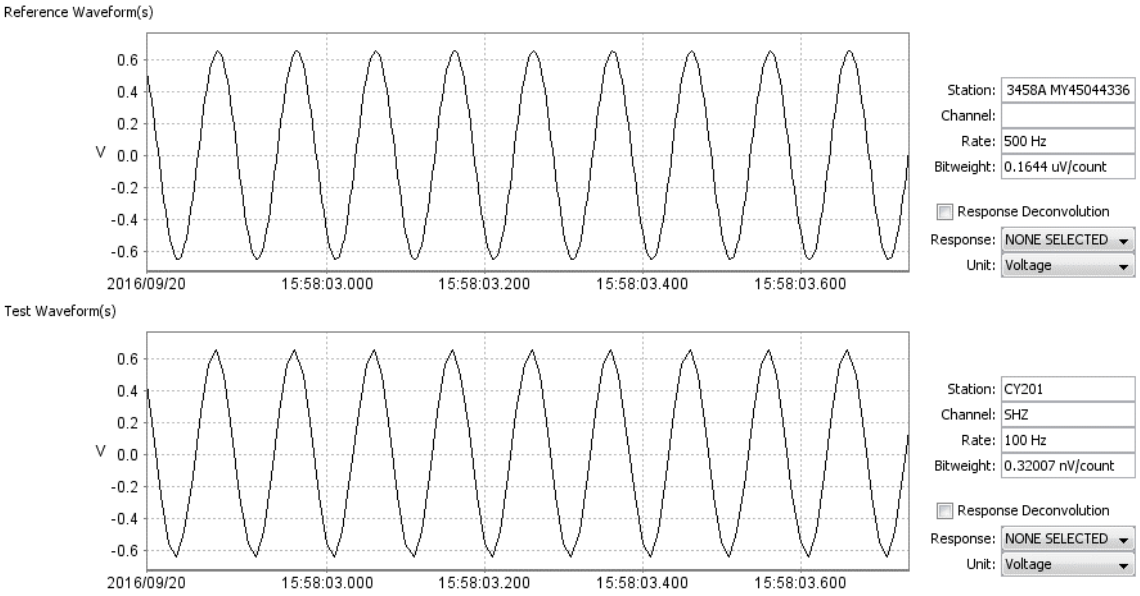


Figure 40 Short-period Full Scale

The table below shows the peak-to-peak voltages measured on the reference meter and each of the broadband and short-period channels for each digitizer with 4 digits of precision after the decimal point.

Table 12 Observed Peak-to-Peak Full Scale Values

Digitizer	BB Meter Voltage	BHZ	BH2	BH1	SP Meter Voltage	SHZ	SH2	SH1
# 1	**2.8000 V**	2.8001 V	2.8001 V	2.8001 V	**1.3016 V**	1.3016 V	1.3017 V	1.3017 V
# 2	**2.8027 V**	2.8029 V	2.8029 V	2.8028 V	**1.3019 V**	1.3021 V	1.3020 V	1.3019 V
# 3	**2.8020 V**	2.8020 V	2.8021 V	2.8020 V	**1.3016 V**	1.3017 V	1.3017 V	1.3017 V
# 4	**2.8002 V**	2.8003 V	2.8003 V	2.8003 V	**1.3017 V**	1.3018 V	1.3018 V	1.3018 V
# 5	**2.8000 V**	2.8002 V	2.8002 V	2.8002 V	**1.3017 V**	1.3017 V	1.3017 V	1.3017 V
# 6	**2.8017 V**	2.8018 V	2.8018 V	2.8018 V	**1.3016 V**	1.3017 V	1.3017 V	1.3017 V
# 7	**2.8000 V**	2.8002 V	2.8002 V	2.8002 V	**1.3016 V**	1.3017 V	1.3017 V	1.3017 V
# 8	**2.8000 V**	2.8002 V	2.8002 V	2.8002 V	**1.3017 V**	1.3017 V	1.3017 V	1.3017 V
# 9	**2.8023 V**	2.8024 V	2.8024 V	2.8024 V	**1.3018 V**	1.3019 V	1.3019 V	1.3019 V
# 10	**2.7995 V**	2.7996 V	2.7996 V	2.7996 V	**1.3014 V**	1.3015 V	1.3015 V	1.3015 V
# 11	**2.7995 V**	2.7996 V	2.7996 V	2.7996 V	**1.3014 V**	1.3015 V	1.3015 V	1.3015 V
# 12	**2.7999 V**	2.8001 V	2.8001 V	2.8001 V	**1.3016 V**	1.3017 V	1.3017 V	1.3017 V
# 13	**2.8000 V**	2.8002 V	2.8002 V	2.8002 V	**1.3016 V**	1.3017 V	1.3017 V	1.3017 V
# 14	**2.8005 V**	2.8006 V	2.8006 V	2.8006 V	**1.3018 V**	1.3019 V	1.3019 V	1.3019 V
# 15	**2.8005 V**	2.8007 V	2.8006 V	2.8007 V	**1.3018 V**	1.3019 V	1.3019 V	1.3019 V
# 16	**2.8000 V**	2.8001 V	2.8002 V	2.8002 V	**1.3016 V**	1.3017 V	1.3017 V	1.3017 V
# 17	**2.7999 V**	2.8000 V	2.8000 V	2.8000 V	**1.3016 V**	1.3017 V	1.3017 V	1.3017 V
# 18	**2.7999 V**	2.8000 V	2.8000 V	2.8000 V	**1.3016 V**	1.3017 V	1.3017 V	1.3017 V

There were no observed signs of clipping on the time series. Any variations in the reported full scale values in the table above are due to the slightly different sinusoid voltage amplitude from the signal generator from one iteration to the next and not actual differences in the channels full scale. In no case was the estimated full-scale values significantly different than nominal. Therefore, the nominal full scale values will be accepted for use.

4.6 Self-Noise

The self-noise spectra of each digitizer input channel was measured by terminating each digitizer input channel with a resistor approximately sized to the resistive impedance of the expected sensor. The data was recorded for a minimum of 8 hours. Note that testing of self-noise within an electronics laboratory is difficult to execute due to diurnal variations in temperature and the presence of interfering electronic and mechanical noise sources. For this reason, the self-noise data was collected after the digitizer had been allowed to thermally stabilize for at least 6 hours and taken from an over-night period when activity was minimal.

The nominal impedance for the broadband channels (BHZ, BH2, and BH1) is 100 ohm and the total noise is measured over 0.02 – 40 Hz. The nominal impedance for the short-period channels (SHZ, SH2, and SH1) is 100 kohm and the total noise is measured over 1.0 – 40 Hz. It is recognized that the channel noise that impacts system performance is not limited to within the 0.02 – 40 Hz and 1 – 40 Hz passbands used above. The total RMS noise and dynamic ranges are only reported within these pass-bands. However, care was taken to ensure that there was not a significant amount of noise present in the channels below the low frequency limit of the pass-band.

For this estimate of the noise power spectra and total RMS noise the bit-weights obtained from the small-signal 10 Hz sensitivity results in Table 7 were used to convert the data from counts to volts for each channel. Only the nominal bitweight for each channel has been applied. No correction for the sensor response has been applied. In addition, for the broadband channels, no correction for the preamplifier response has been applied. This is due to the digitizer self-noise being dominated by components after the preamplifier filter.

The digitizer self-noise was observed to vary considerably across the digitizers. In addition, there was no established requirement for the acceptable level of noise that would be allowed. Earlier evaluations of the prototype digitizers during GEQ testing served to provide a reference point for what to expect. However, it is important to note that the digitizer design did incorporate some changes in between GEQ testing and the fabrication of the production units in order to improve the over-voltage protection circuitry. It was believed that this change would result in a slight, but un-quantified, increase in self-noise.

As the production digitizers were evaluated and some were determined to have noise characteristics that deviated significantly from the GEQ, it became necessary to engage the USAF and Navy about what would be an acceptable level of noise. It was determined by the USAF that in order to minimize impact to the mission performance of the system, the following requirements for self-noise would be adhered to:

- Self-noise power spectra, when de-convolved by the expected seismometer response model, shall be a minimum of 6 dB below the established site low noise model for the ocean floor in the Mediterranean across 0.02 – 40 Hz for the broadband channels and 0.5 – 40 Hz for the short-period channels.
- Time-series data shall not have notable discontinuities or glitches.

The self-noise power spectra in units of voltage are shown for each digitizer in the following subsections. The self-noise power spectra values are included in Appendix B: Self-Noise.

The total RMS noise is computed for the broadband channels over 0.02 – 40 Hz and for the short-period channels over 1 – 40 Hz.

Table 13 Digitizer Self-Noise (RMS)

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
# 1	430.39 nV rms	411.84 nV rms	429.31 nV rms	436.64 nV rms	337.14 nV rms	338.73 nV rms
# 2	453.54 nV rms	447.86 nV rms	531.73 nV rms	355.95 nV rms	374.02 nV rms	355.76 nV rms
# 3	426.47 nV rms	402.08 nV rms	397.74 nV rms	337.62 nV rms	349.64 nV rms	338.91 nV rms
# 4	401.08 nV rms	415.69 nV rms	486.22 nV rms	348.91 nV rms	364.62 nV rms	361.35 nV rms
# 5	582.34 nV rms	650.12 nV rms	832.76 nV rms	415.29 nV rms	393.75 nV rms	396.96 nV rms
# 6	443.64 nV rms	629.09 nV rms	518.28 nV rms	379.37 nV rms	461.73 nV rms	358.45 nV rms
# 7	520.15 nV rms	571.74 nV rms	632.57 nV rms	352.78 nV rms	357.56 nV rms	366.13 nV rms
# 8	595.22 nV rms	729.15 nV rms	878.22 nV rms	351.11 nV rms	365.12 nV rms	441.90 nV rms
# 9	399.60 nV rms	440.40 nV rms	404.65 nV rms	369.33 nV rms	350.86 nV rms	347.89 nV rms
# 10	432.82 nV rms	446.27 nV rms	443.12 nV rms	342.85 nV rms	345.44 nV rms	358.88 nV rms
# 11	602.85 nV rms	766.76 nV rms	699.55 nV rms	393.87 nV rms	403.83 nV rms	389.20 nV rms
# 12	608.13 nV rms	731.35 nV rms	733.22 nV rms	401.74 nV rms	767.66 nV rms	465.44 nV rms
# 13	531.85 nV rms	526.96 nV rms	536.44 nV rms	353.40 nV rms	337.68 nV rms	342.94 nV rms
# 14	397.08 nV rms	495.07 nV rms	569.36 nV rms	347.96 nV rms	353.85 nV rms	346.32 nV rms
# 15	410.39 nV rms	449.22 nV rms	442.84 nV rms	372.81 nV rms	355.32 nV rms	349.45 nV rms
# 16	409.35 nV rms	398.68 nV rms	417.49 nV rms	354.29 nV rms	344.79 nV rms	416.90 nV rms
# 17	529.73 nV rms	604.34 nV rms	637.55 nV rms	347.59 nV rms	583.74 nV rms	349.31 nV rms
# 18	630.92 nV rms	668.49 nV rms	882.49 nV rms	380.58 nV rms	354.67 nV rms	362.55 nV rms

4.6.1 Digitizer # 1

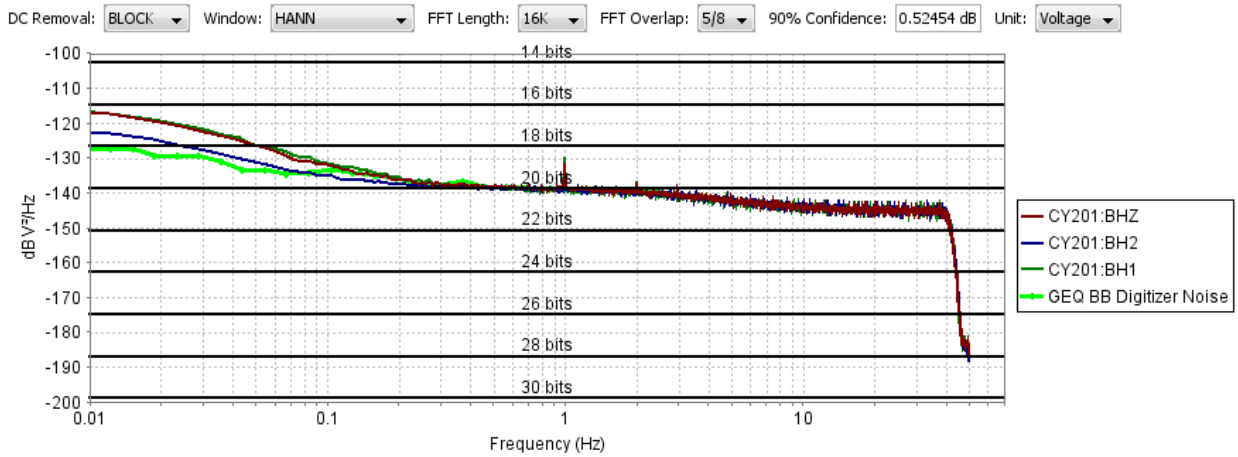


Figure 41 Digitizer #1 Broadband Self-Noise

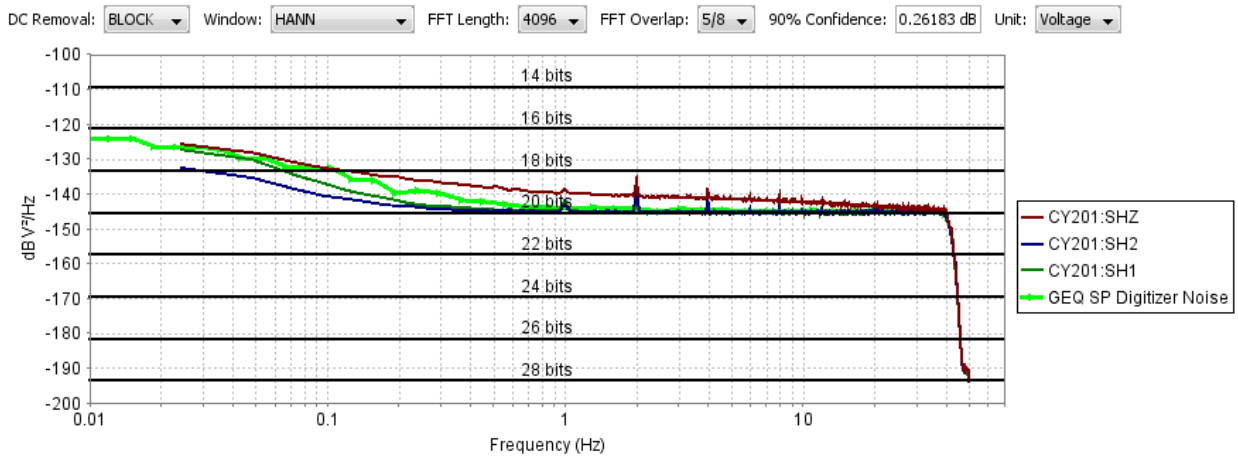


Figure 42 Digitizer #1 Short-period Self-Noise

4.6.2 Digitizer # 2

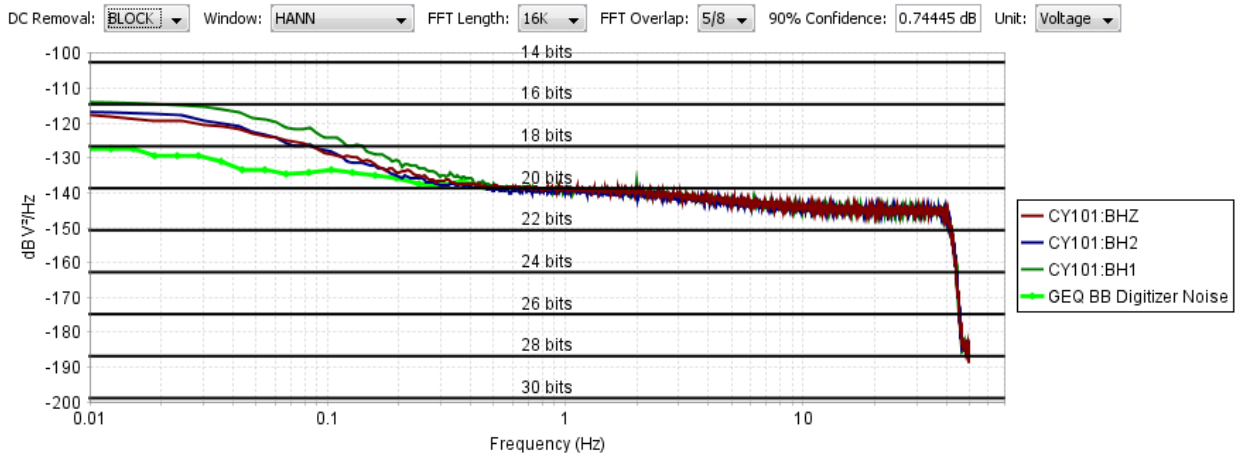


Figure 43 Digitizer #2 Broadband Self-Noise

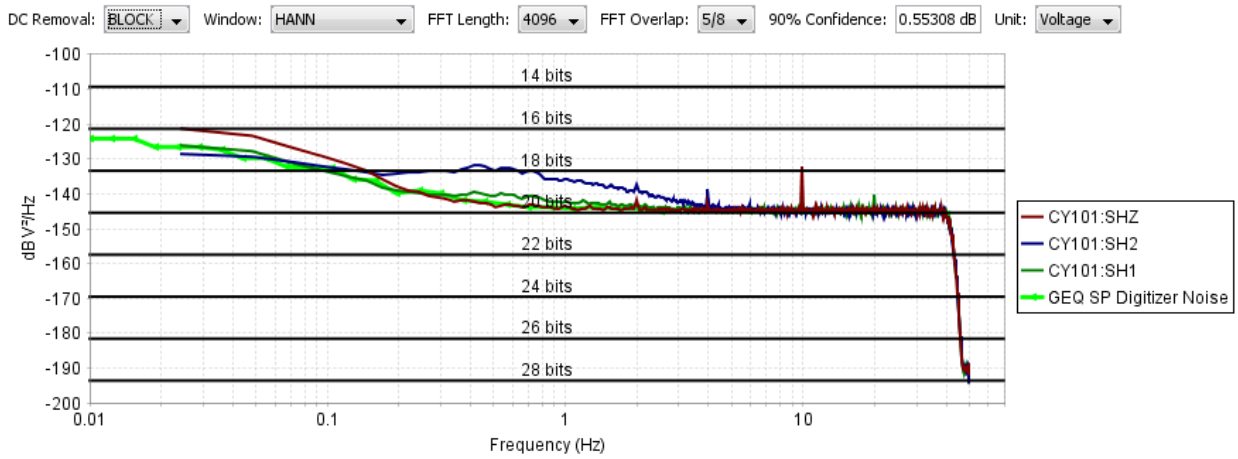


Figure 44 Digitizer #2 Short-period Self-Noise

4.6.3 Digitizer # 3

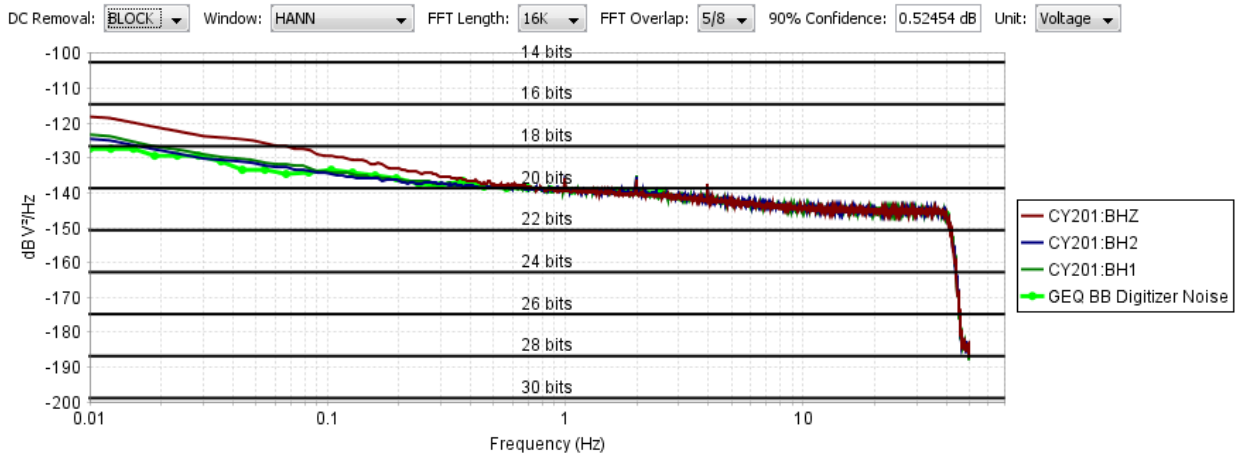


Figure 45 Digitizer #3 Broadband Self-Noise

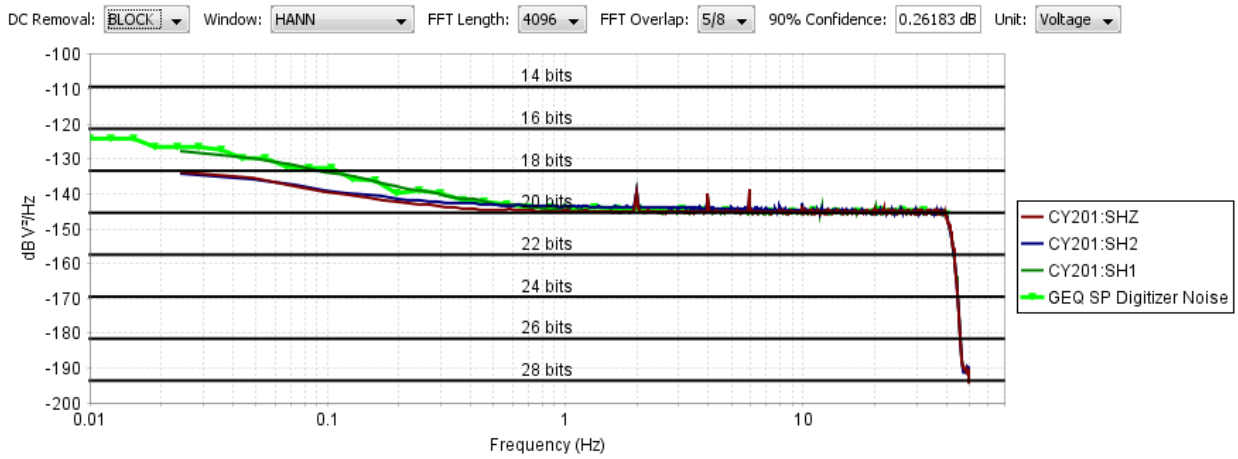


Figure 46 Digitizer #3 Short-period Self-Noise

4.6.4 Digitizer # 4

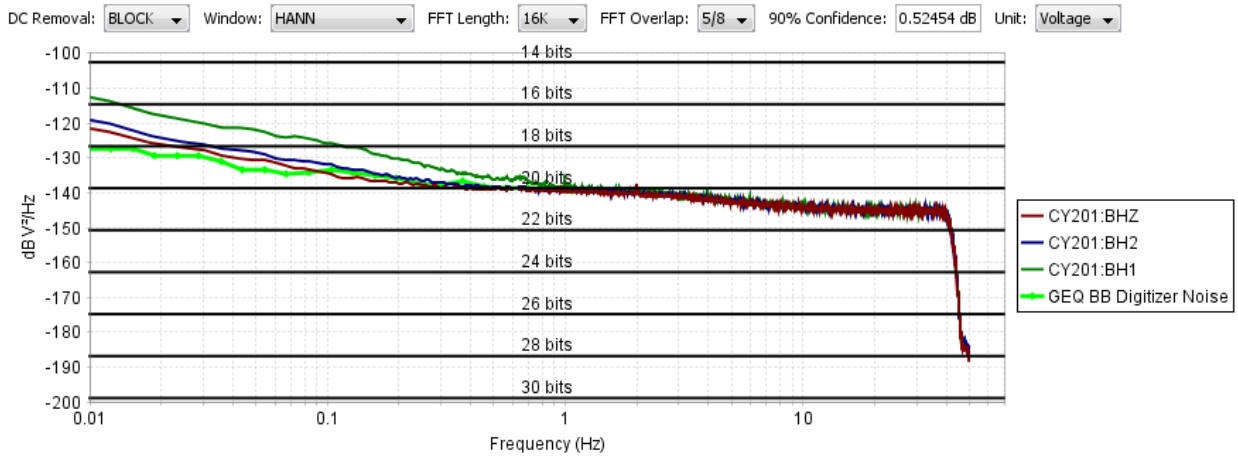


Figure 47 Digitizer #4 Broadband Self-Noise

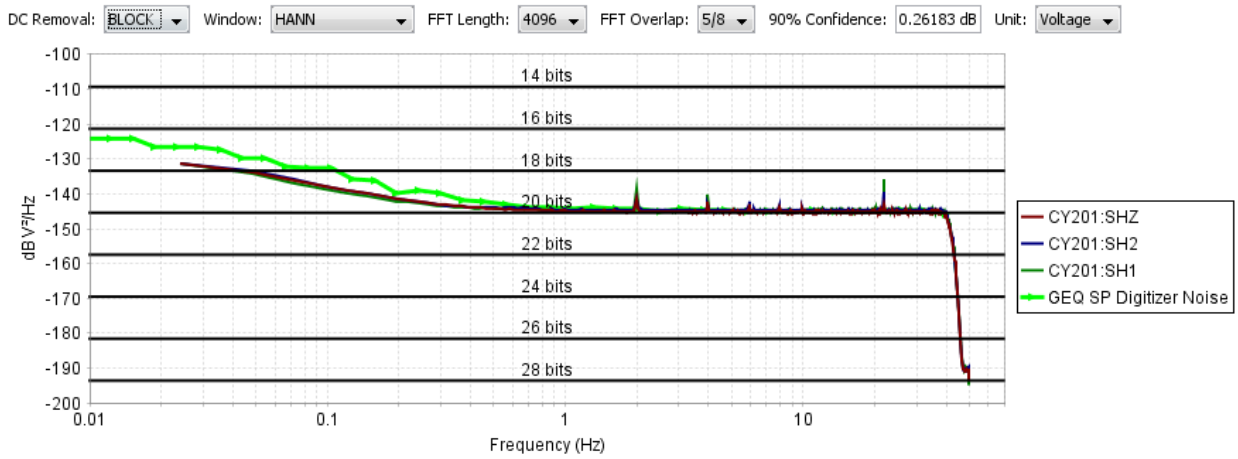


Figure 48 Digitizer #4 Short-period Self-Noise

4.6.5 Digitizer # 5

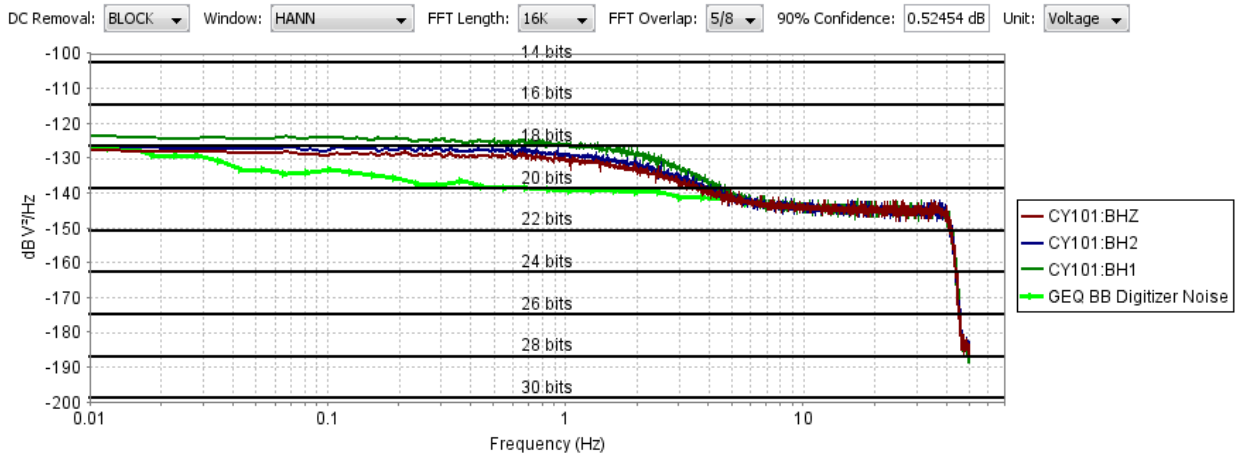


Figure 49 Digitizer #5 Broadband Self-Noise

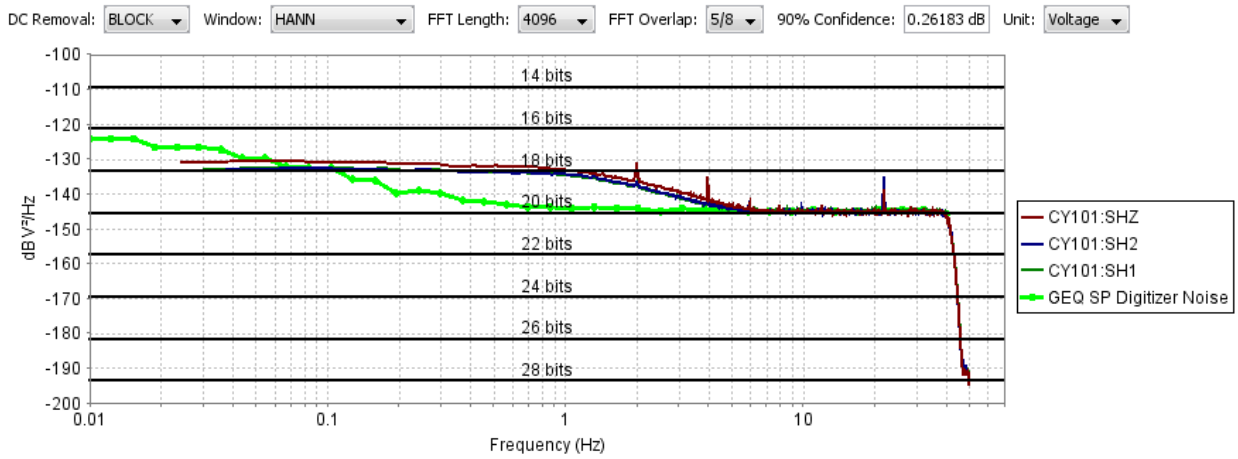


Figure 50 Digitizer #5 Short-period Self-Noise

4.6.6 Digitizer # 6

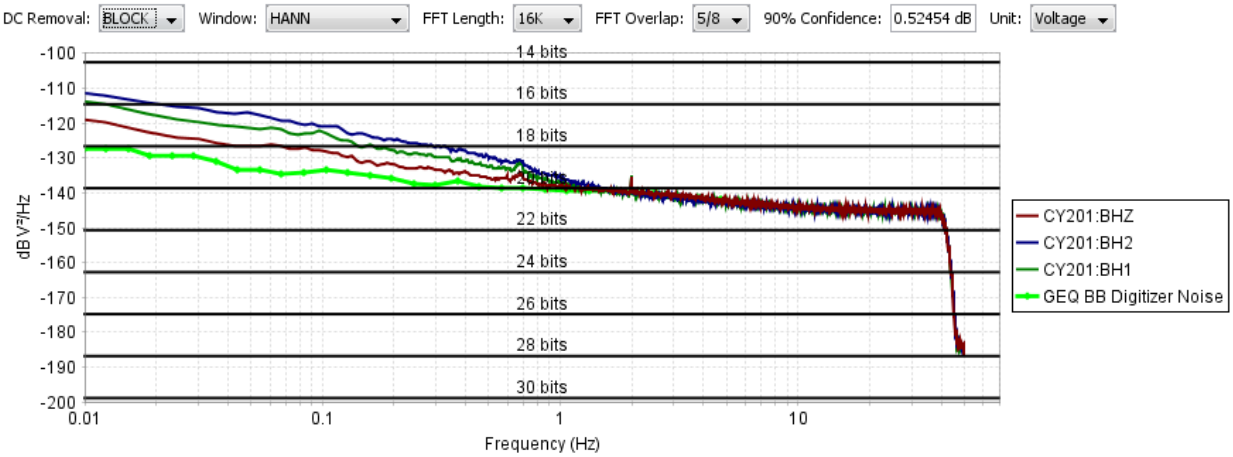


Figure 51 Digitizer #6 Broadband Self-Noise

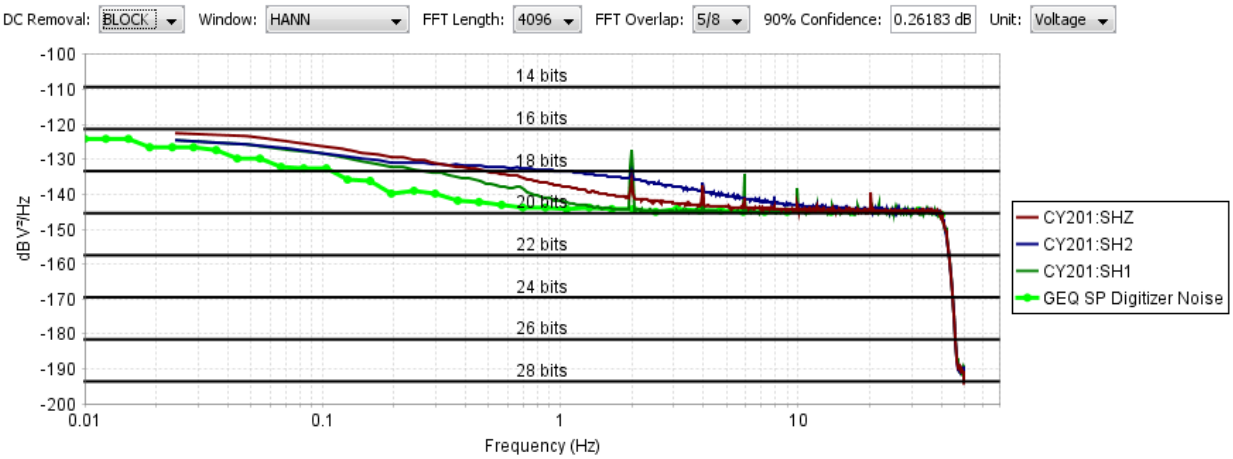


Figure 52 Digitizer #6 Short-period Self-Noise

4.6.7 Digitizer # 7

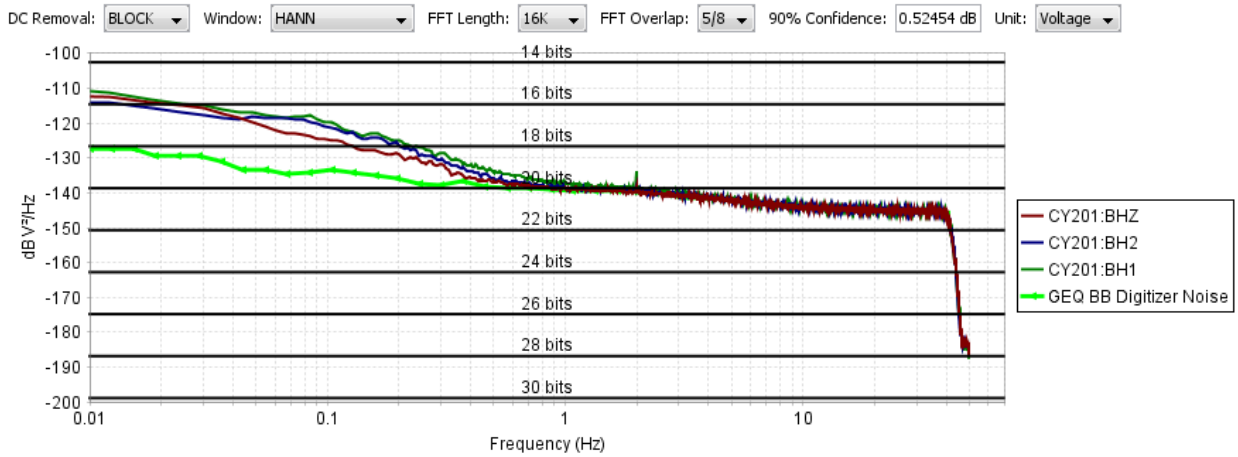


Figure 53 Digitizer #7 Broadband Self-Noise

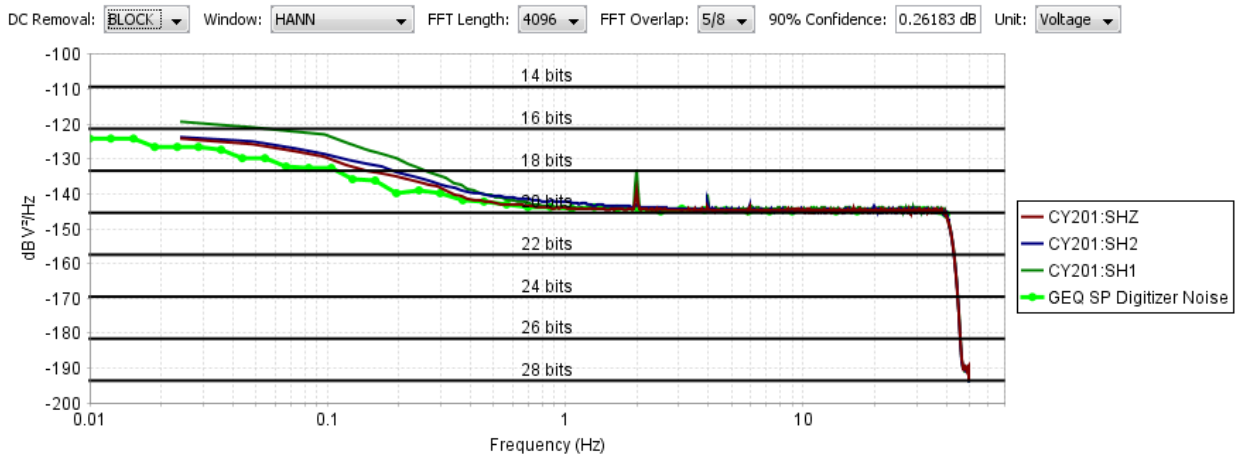


Figure 54 Digitizer #7 Short-period Self-Noise

4.6.8 Digitizer # 8

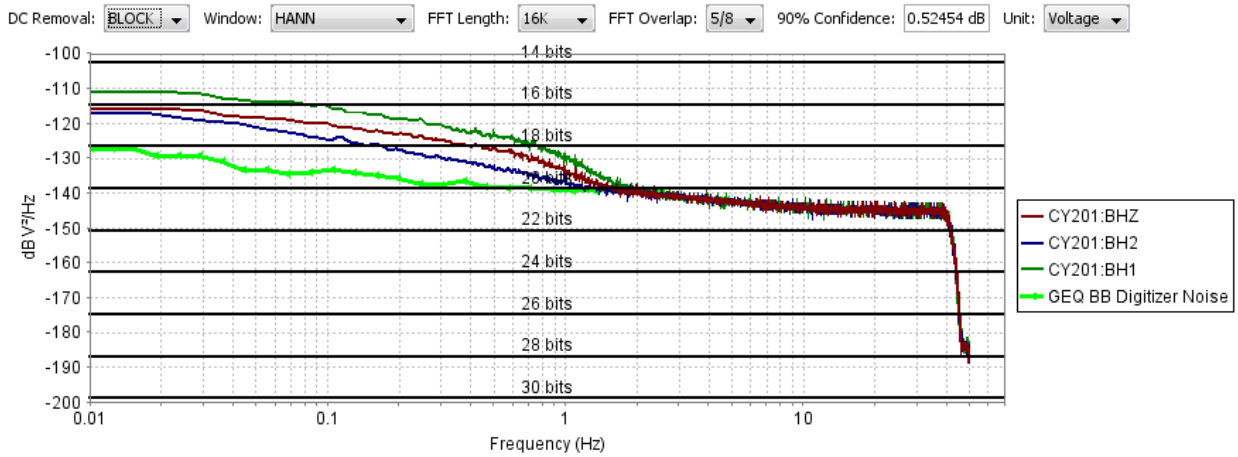


Figure 55 Digitizer #8 Broadband Self-Noise

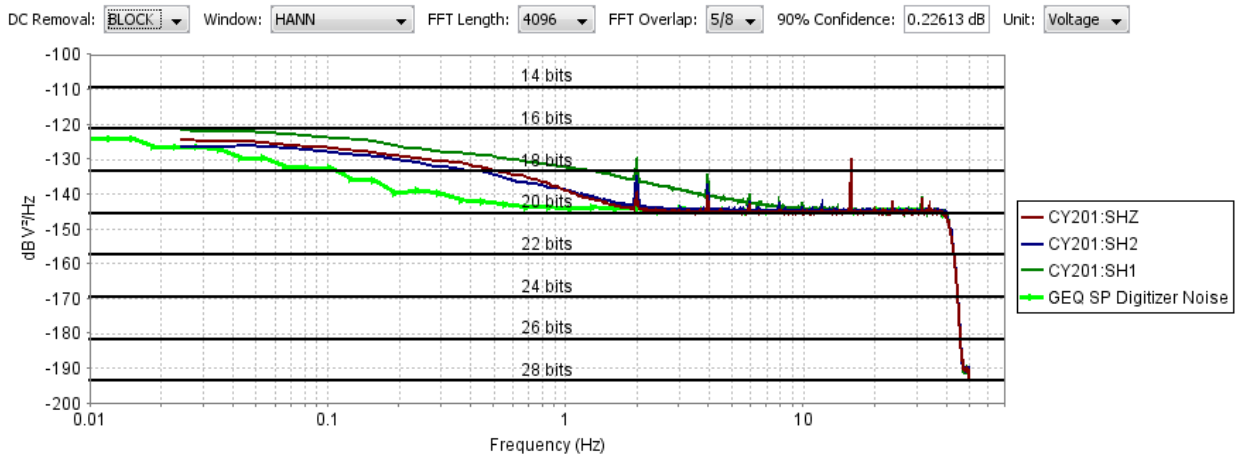


Figure 56 Digitizer #8 Short-period Self-Noise

4.6.9 Digitizer # 9

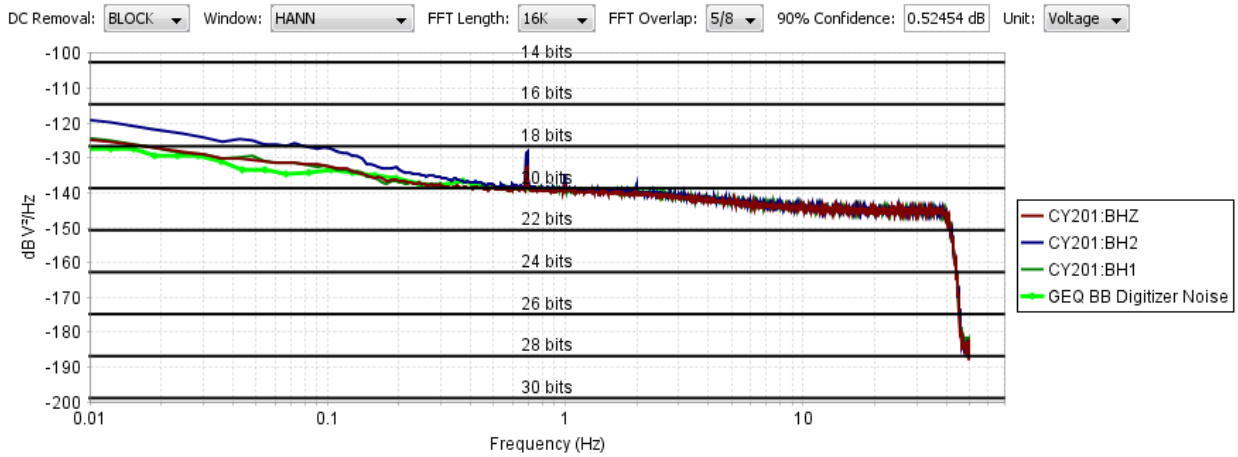


Figure 57 Digitizer #9 Broadband Self-Noise

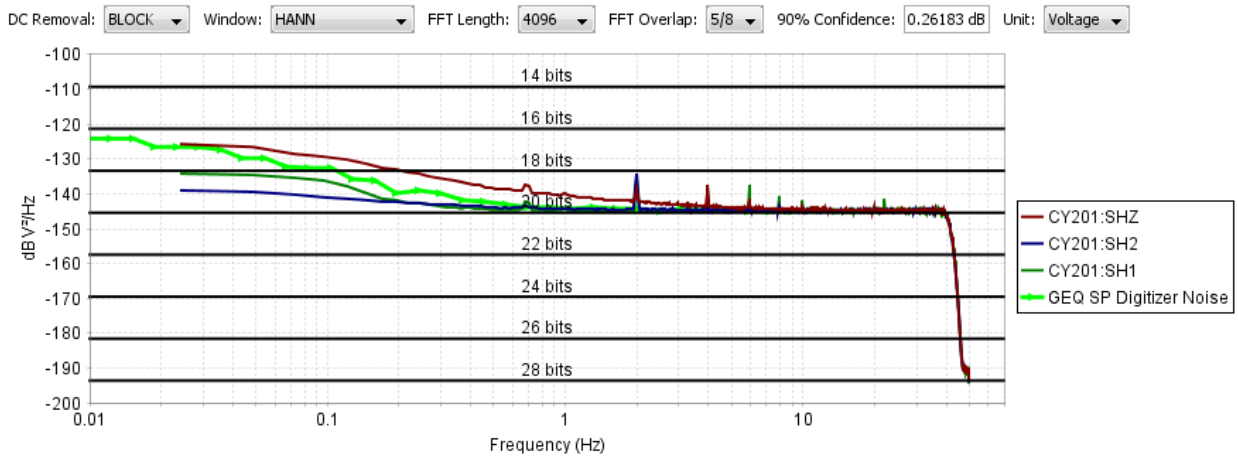


Figure 58 Digitizer #9 Short-period Self-Noise

4.6.10 Digitizer # 10

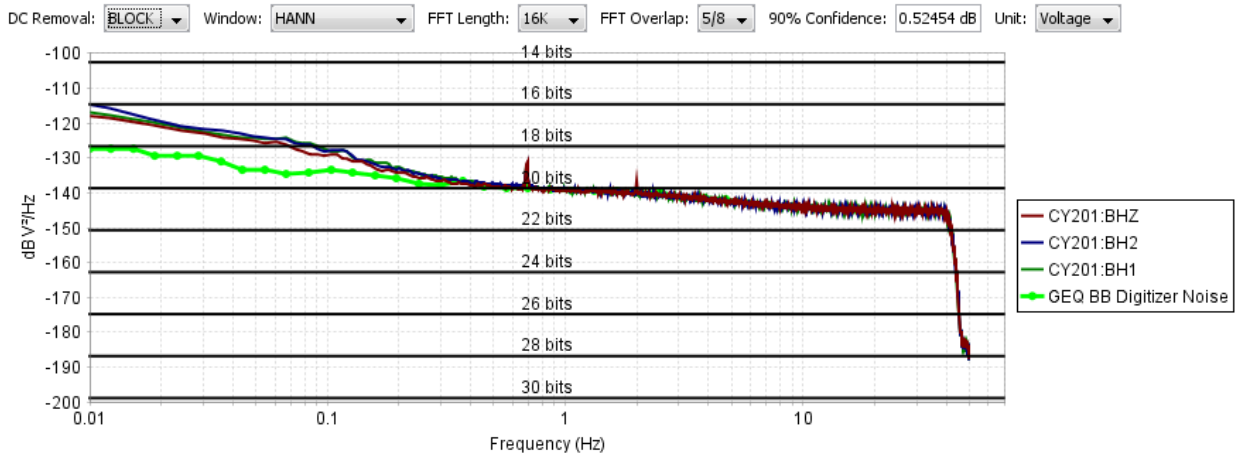


Figure 59 Digitizer #10 Broadband Self-Noise

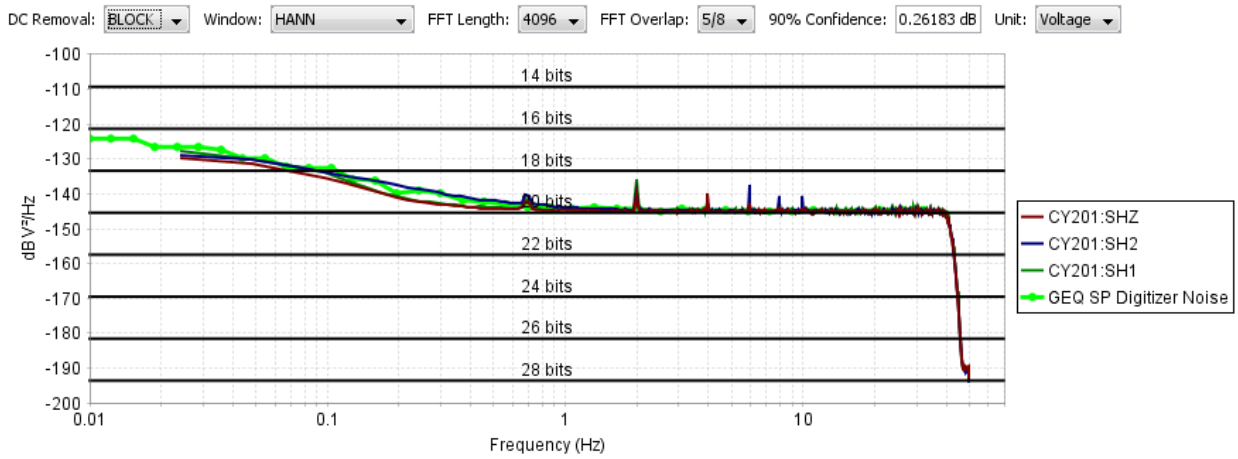


Figure 60 Digitizer #10 Short-period Self-Noise

4.6.11 Digitizer # 11

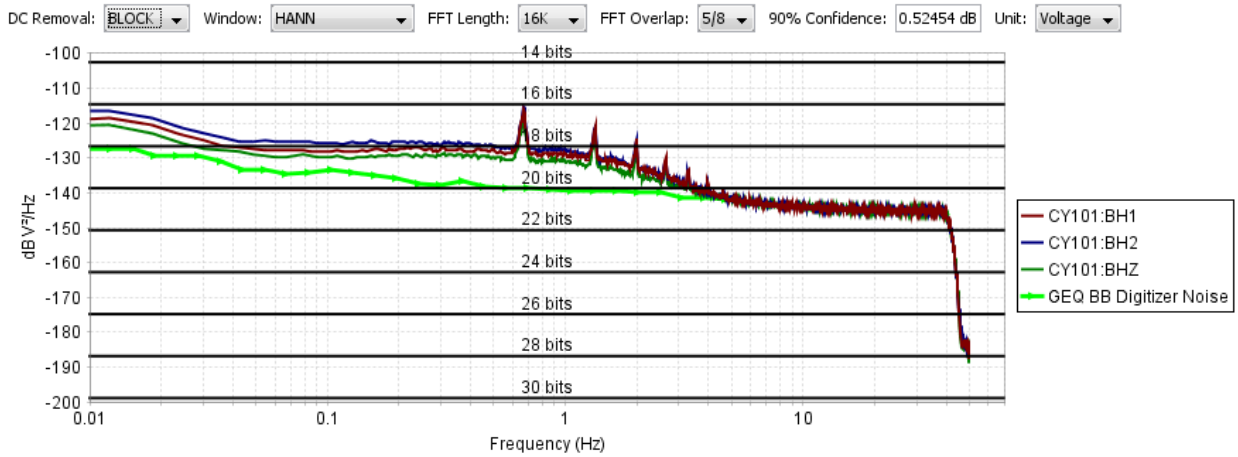


Figure 61 Digitizer #11 Broadband Self-Noise

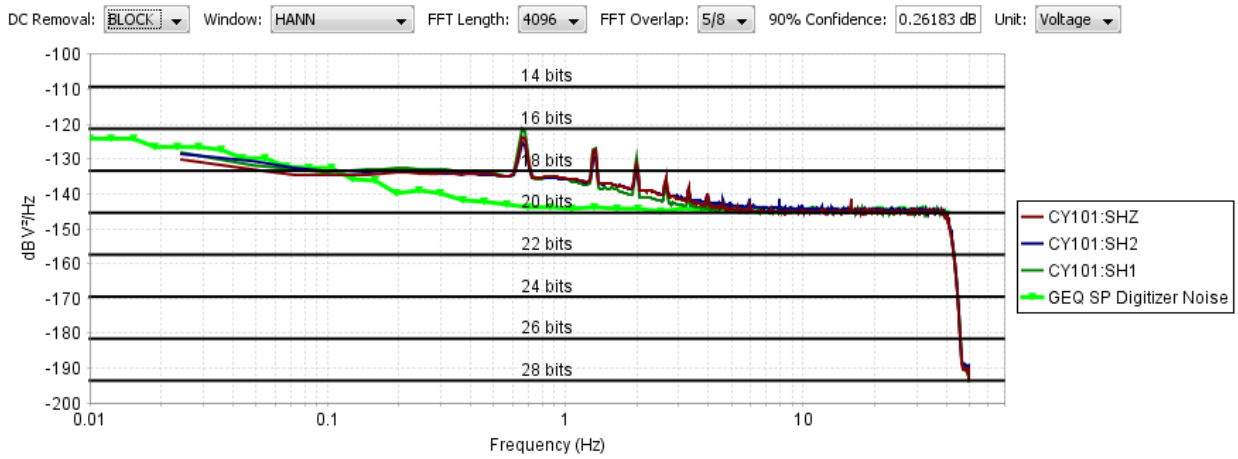


Figure 62 Digitizer #11 Short-period Self-Noise

4.6.12 Digitizer # 12

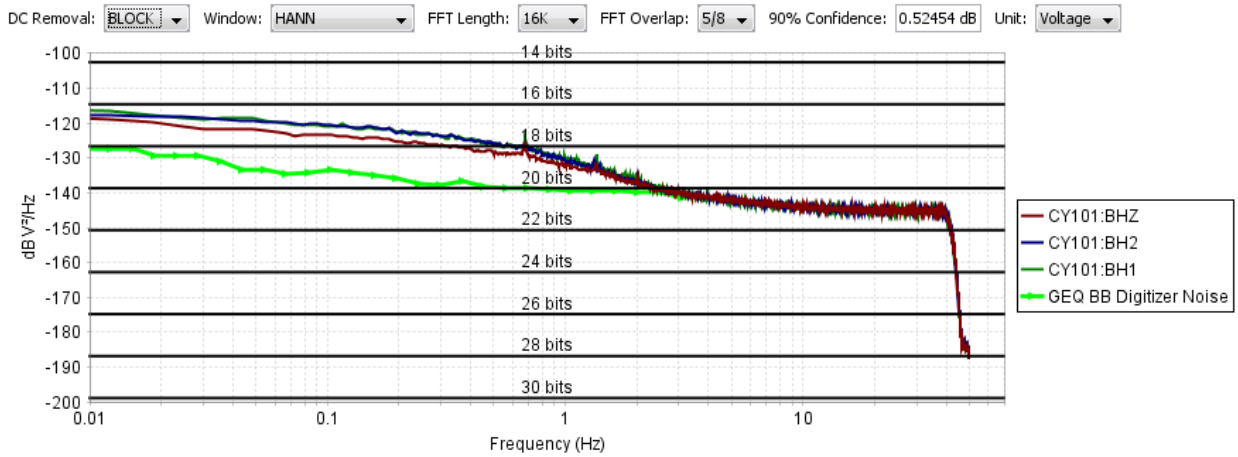


Figure 63 Digitizer #12 Broadband Self-Noise

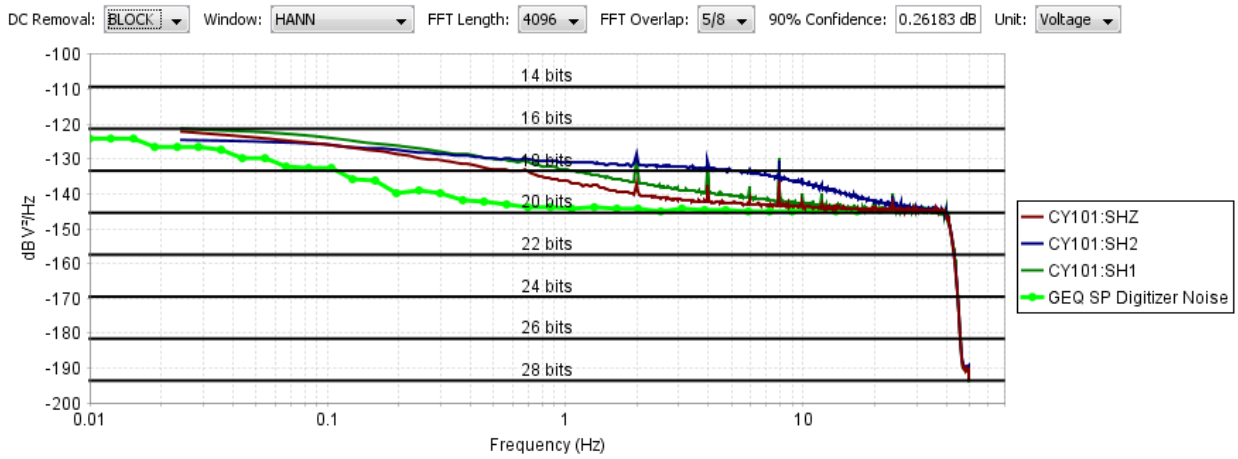


Figure 64 Digitizer #12 Short-period Self-Noise

4.6.13 Digitizer # 13

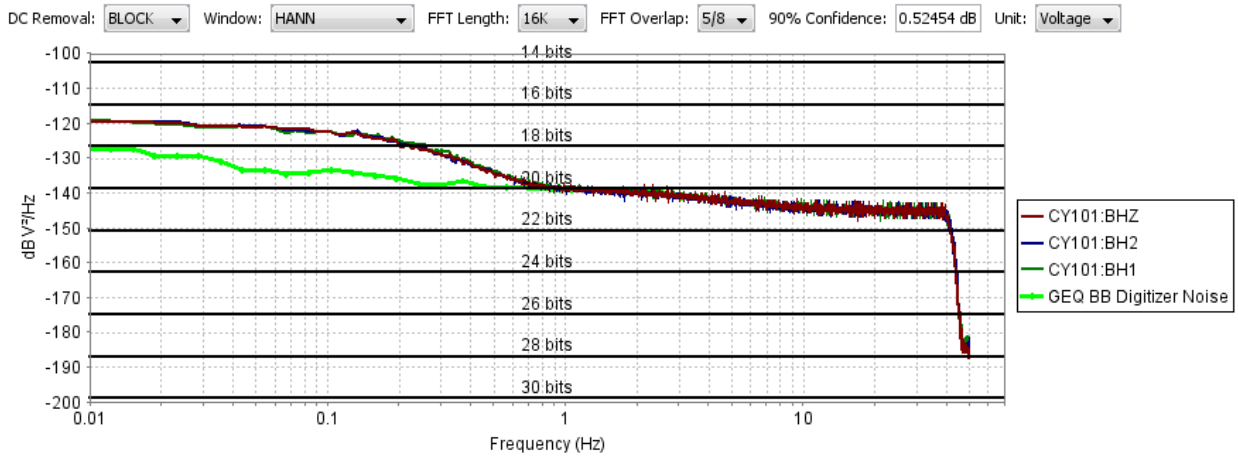


Figure 65 Digitizer #13 Broadband Self-Noise

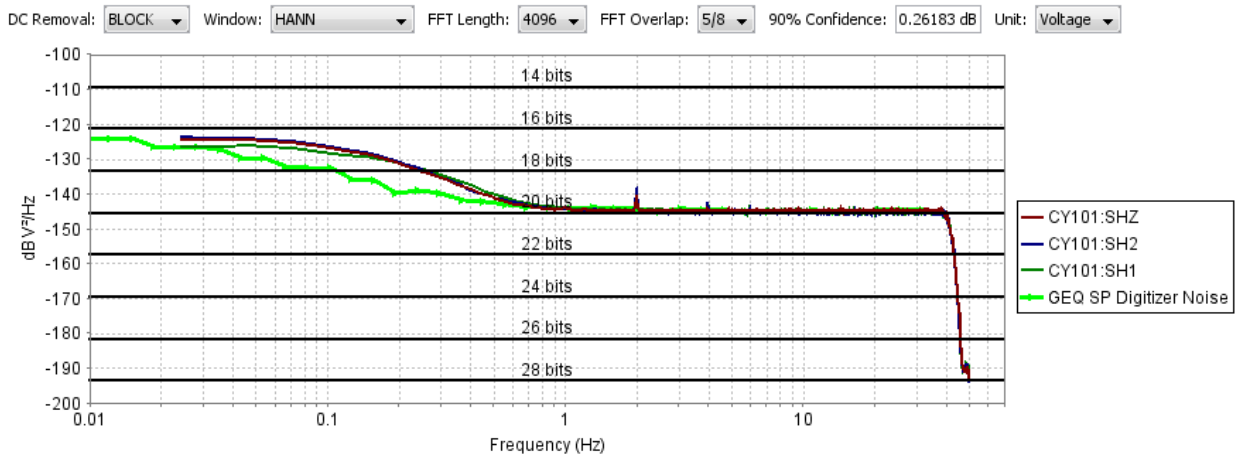


Figure 66 Digitizer #13 Short-period Self-Noise

4.6.14 Digitizer # 14

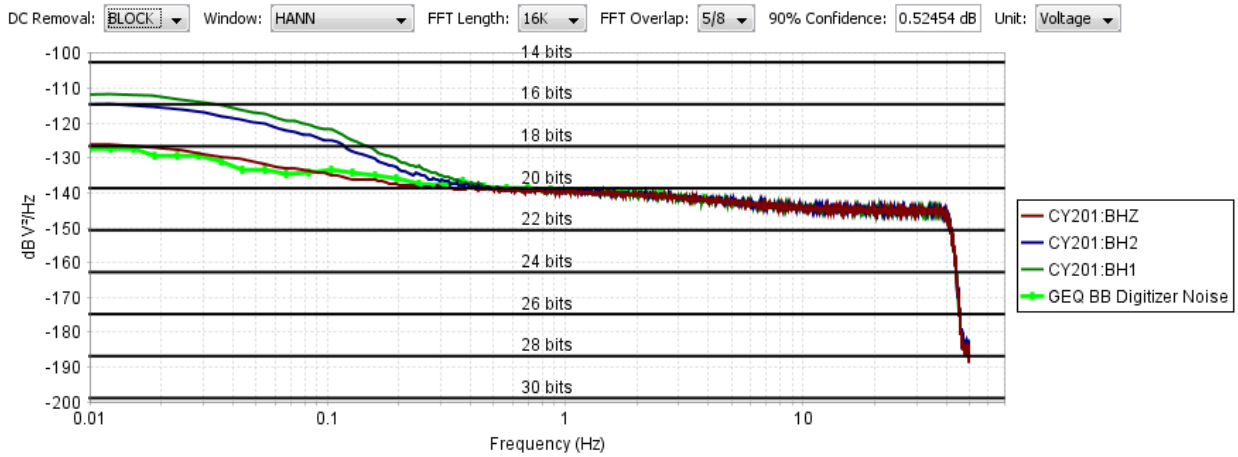


Figure 67 Digitizer #14 Broadband Self-Noise

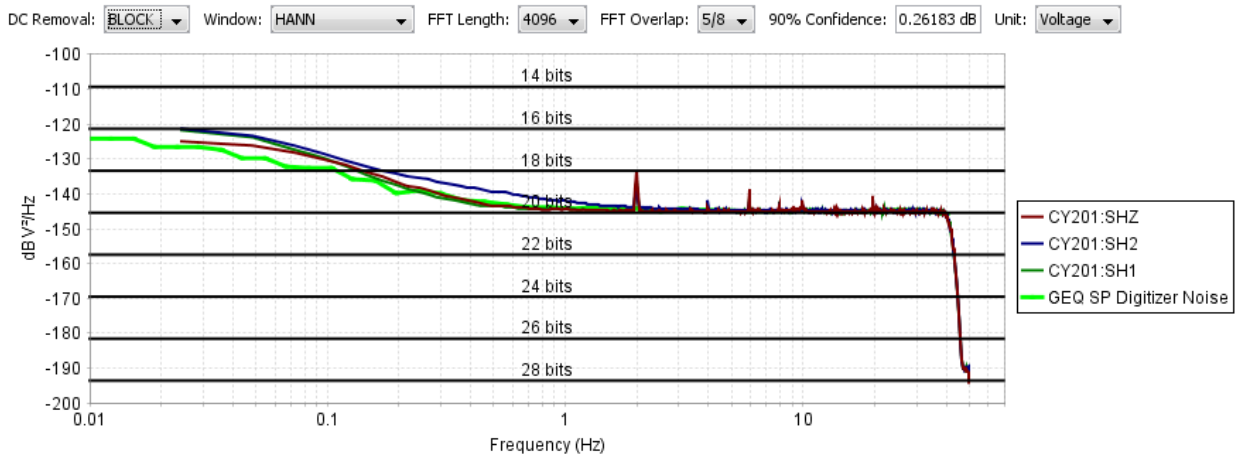


Figure 68 Digitizer #14 Short-period Self-Noise

4.6.15 Digitizer # 15

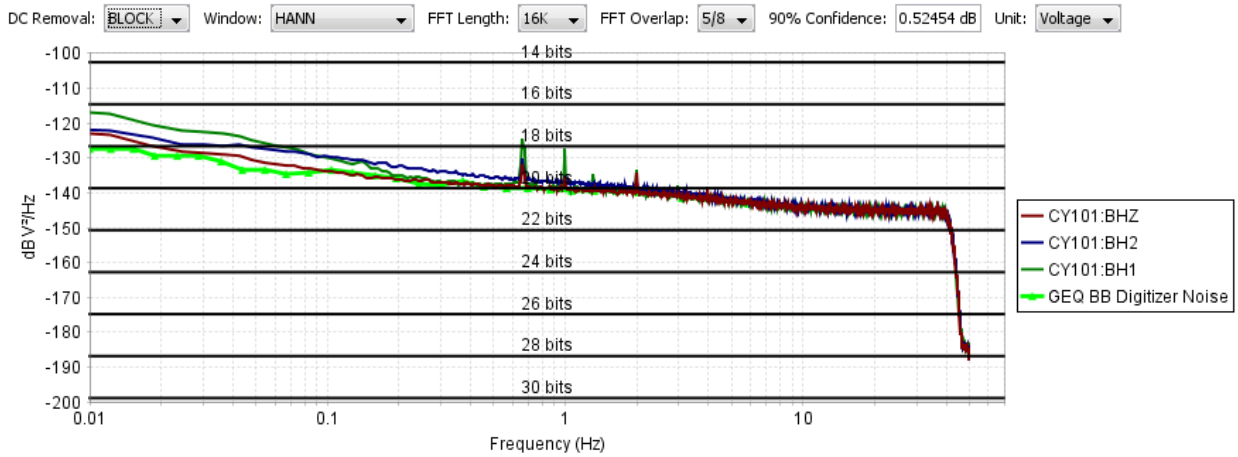


Figure 69 Digitizer #15 Broadband Self-Noise

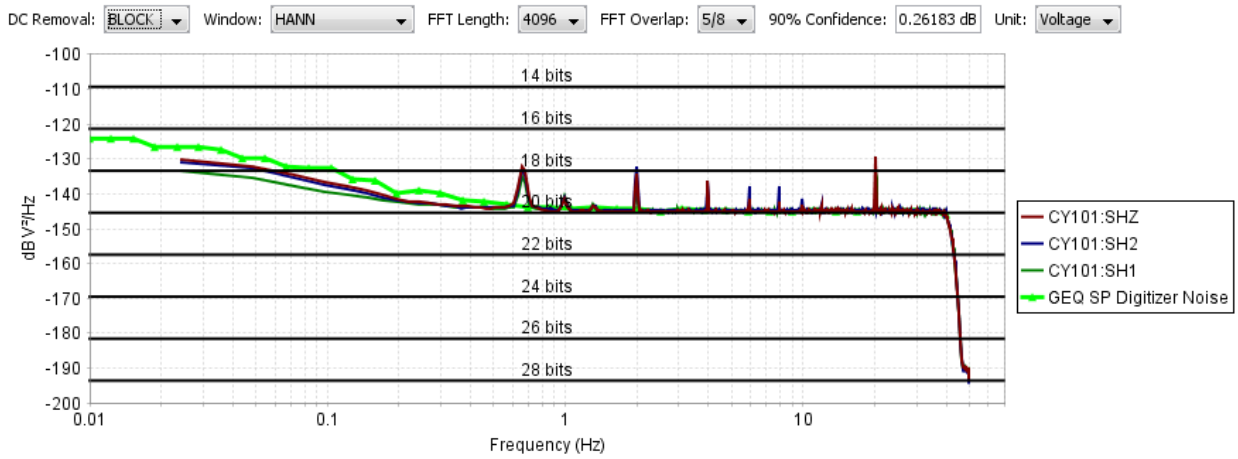


Figure 70 Digitizer #15 Short-period Self-Noise

4.6.16 Digitizer # 16

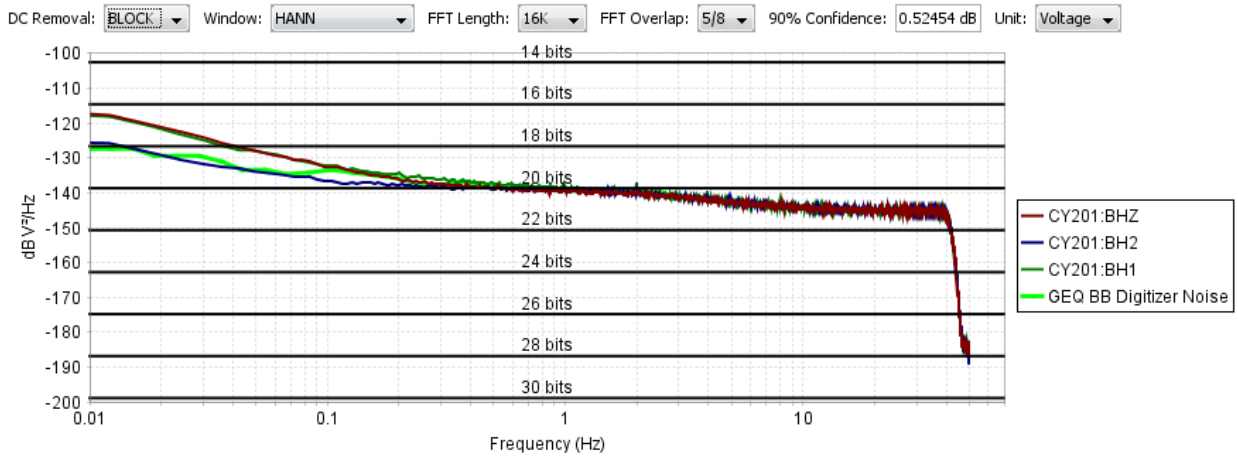


Figure 71 Digitizer #16 Broadband Self-Noise

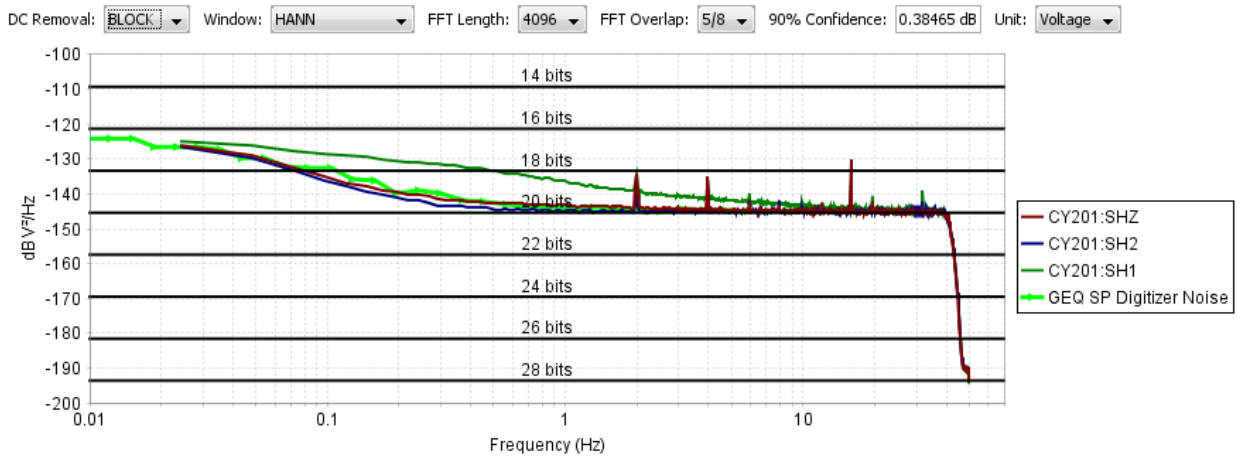


Figure 72 Digitizer #16 Short-period Self-Noise

4.6.17 Digitizer # 17

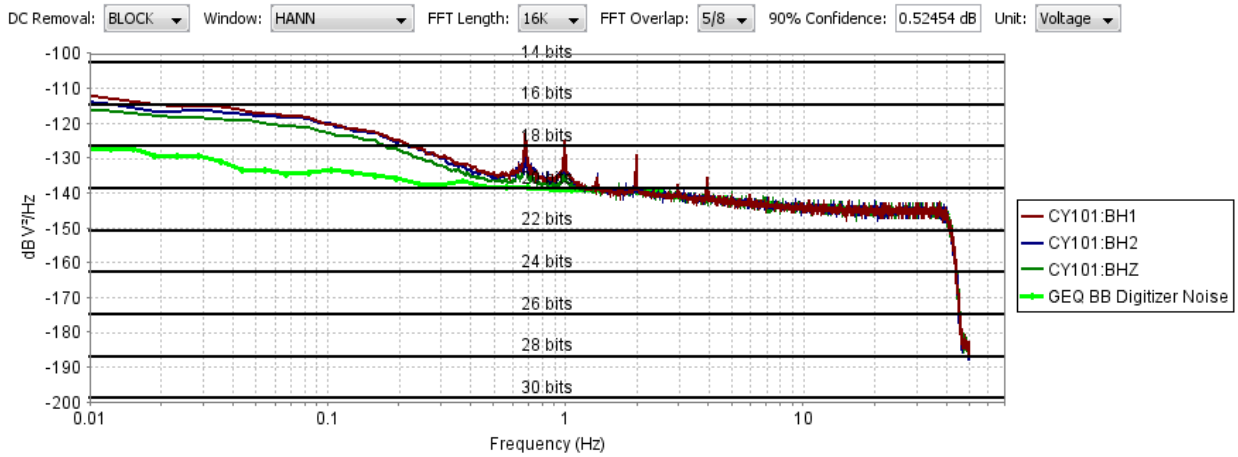


Figure 73 Digitizer #17 Broadband Self-Noise

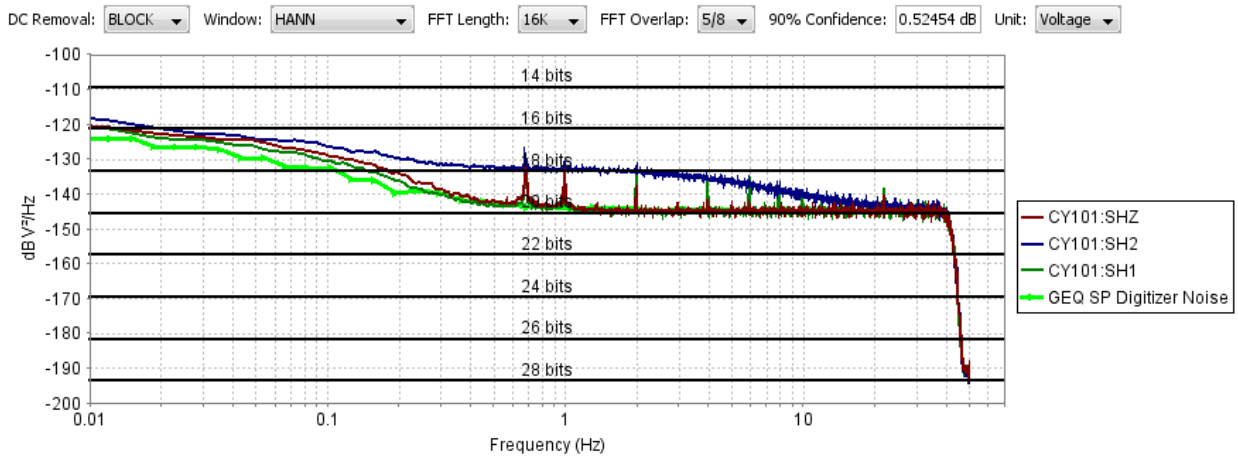


Figure 74 Digitizer #17 Short-period Self-Noise

4.6.18 Digitizer # 18

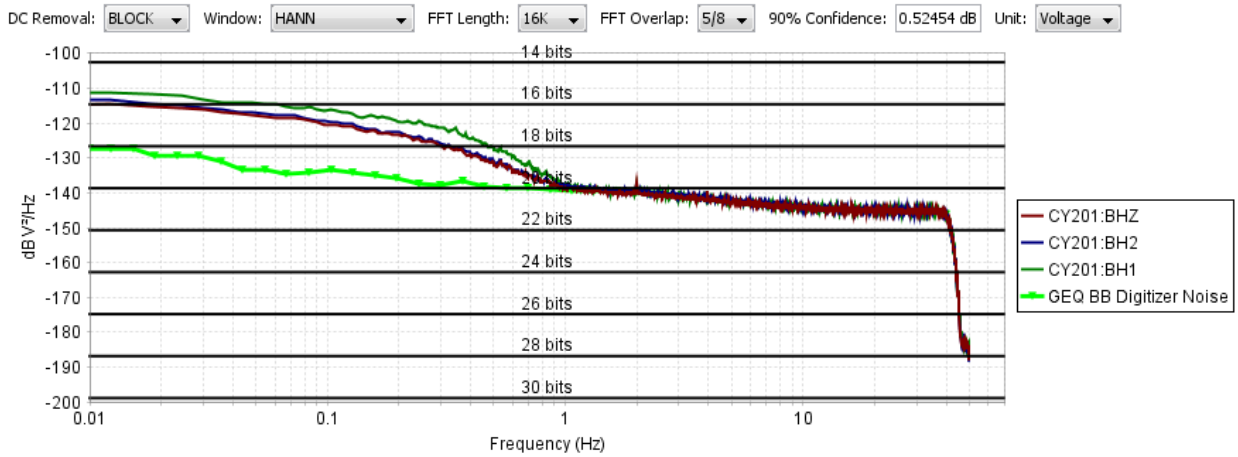


Figure 75 Digitizer #18 Broadband Self-Noise

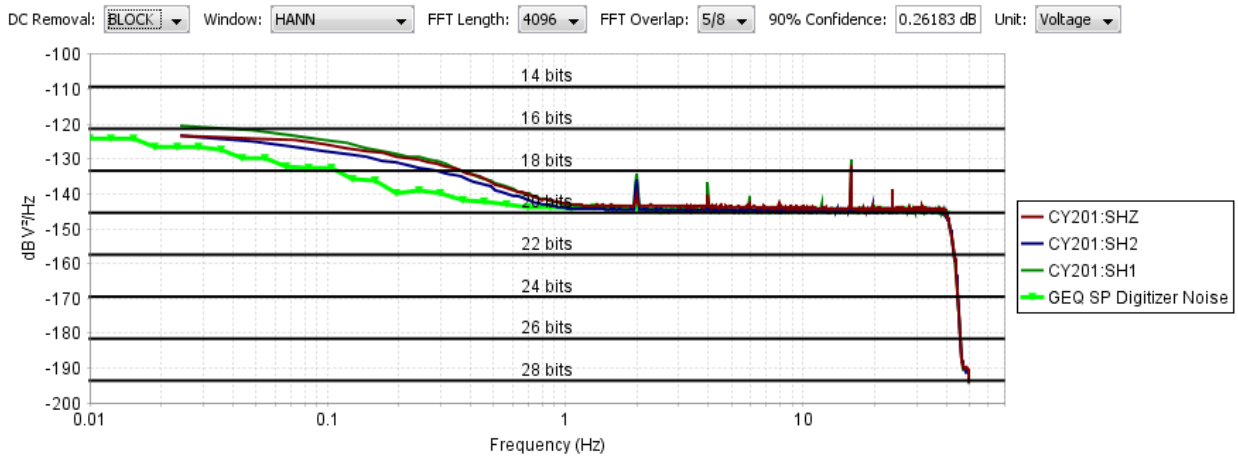


Figure 76 Digitizer #18 Short-period Self-Noise

4.7 Dynamic Range

The dynamic range was estimated as the ratio between the power in a full-scale sinusoid and the power in the self-noise over the application passband. The full-scale value used for the broadband channels is 2.8 V peak-to-peak and for the short-period channels is 1.3 V peak-to-peak. The application passband for the broadband channels is 0.02 – 40 Hz and for the short-period channels is 1 – 40 Hz.

Table 14 Digitizer Dynamic Range

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
# 1	127.23 dB	127.62 dB	127.26 dB	120.45 dB	122.69 dB	122.65 dB
# 2	125.80 dB	125.91 dB	124.41 dB	122.22 dB	121.79 dB	122.22 dB
# 3	127.31 dB	127.83 dB	127.92 dB	122.68 dB	122.38 dB	122.65 dB
# 4	127.85 dB	127.54 dB	126.18 dB	122.39 dB	122.01 dB	122.09 dB
# 5	124.61 dB	123.65 dB	121.50 dB	120.88 dB	121.34 dB	121.27 dB
# 6	126.97 dB	123.94 dB	125.62 dB	121.67 dB	119.96 dB	122.16 dB
# 7	125.59 dB	124.77 dB	123.89 dB	122.30 dB	122.18 dB	121.98 dB
# 8	124.42 dB	122.66 dB	121.04 dB	122.34 dB	122.00 dB	120.34 dB
# 9	127.88 dB	127.04 dB	127.77 dB	121.90 dB	122.35 dB	122.42 dB
# 10	127.19 dB	126.92 dB	126.98 dB	122.55 dB	122.48 dB	122.15 dB
# 11	124.31 dB	122.22 dB	123.02 dB	121.34 dB	121.12 dB	121.44 dB
# 12	124.23 dB	122.63 dB	122.61 dB	121.17 dB	115.54 dB	119.89 dB
# 13	125.40 dB	125.48 dB	125.32 dB	122.28 dB	122.68 dB	122.54 dB
# 14	127.93 dB	126.02 dB	124.80 dB	122.42 dB	122.27 dB	122.46 dB
# 15	127.65 dB	126.86 dB	126.99 dB	121.82 dB	122.24 dB	122.38 dB
# 16	127.67 dB	127.90 dB	127.50 dB	122.26 dB	122.50 dB	120.85 dB
# 17	125.43 dB	124.29 dB	123.82 dB	122.43 dB	117.92 dB	122.38 dB
# 18	123.91 dB	123.41 dB	121.00 dB	121.64 dB	122.25 dB	122.06 dB

4.8 Seismic System Noise

The power spectra of the seismic system noise were determined by applying the respective sensor responses to the input terminated self-noise data to estimate the self-noise levels in units of velocity. The Navy response model was de-convolved from the short-period channels. The Trillium and digitizer preamplifier response models were de-convolved from the broadband channels. The plots of the system noise power spectra are shown below along with the overlaid high and low noise models that were determined for the ocean bottom in the Mediterranean.

4.8.1 Digitizer # 1

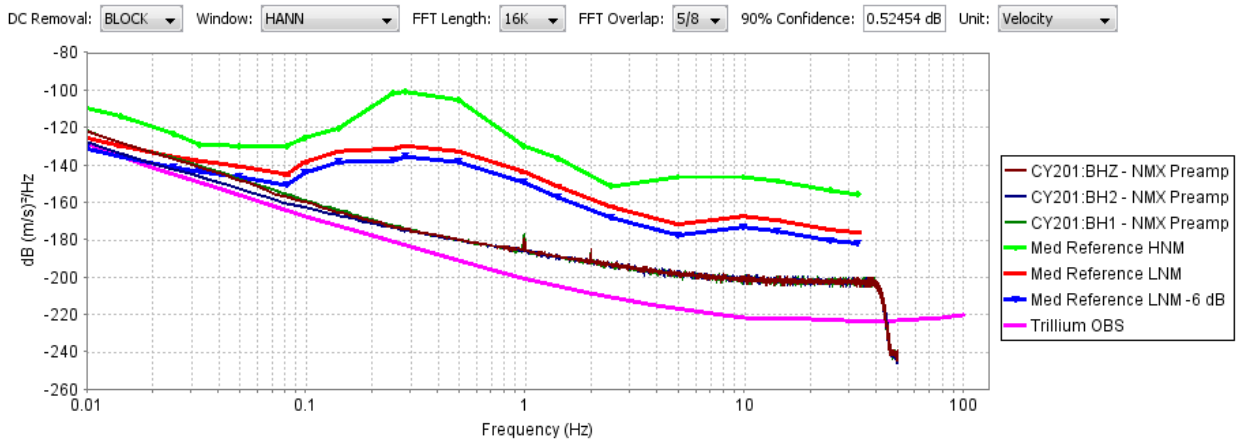


Figure 77 Digitizer #1 Broadband Seismic System Noise

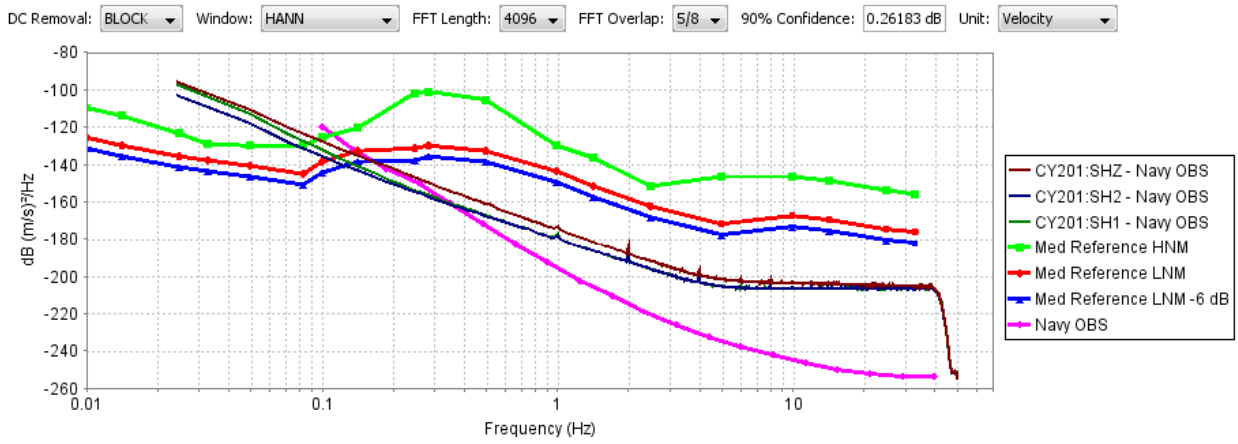


Figure 78 Digitizer #1 Short-period Seismic System Noise

4.8.2 *Digitizer # 2*

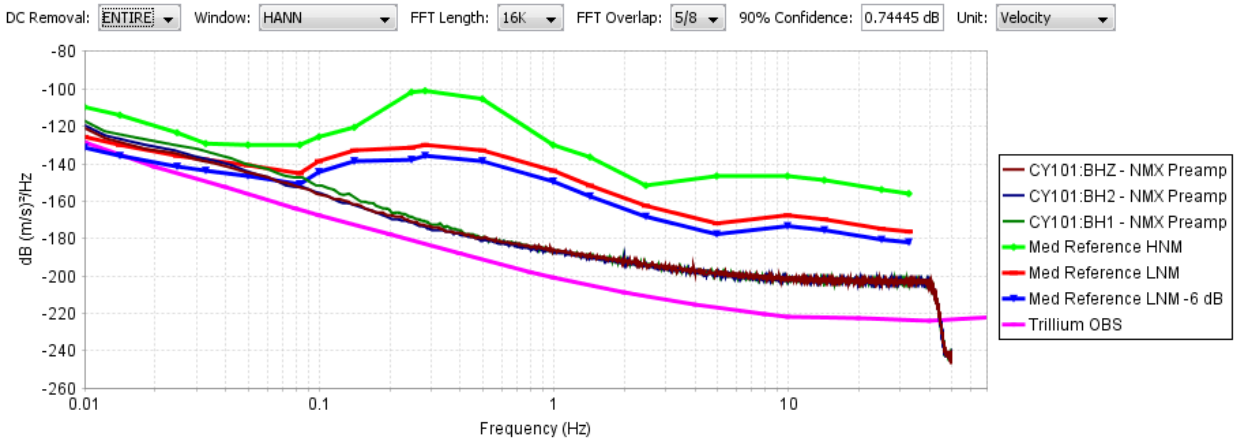


Figure 79 Digitizer #2 Broadband Seismic System Noise

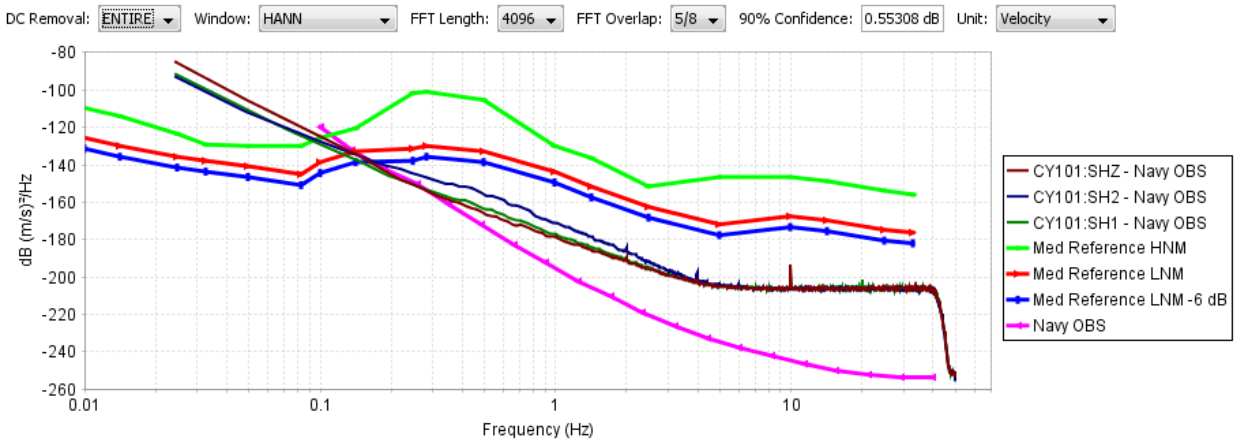


Figure 80 Digitizer #2 Short-period Seismic System Noise

4.8.3 *Digitizer # 3*

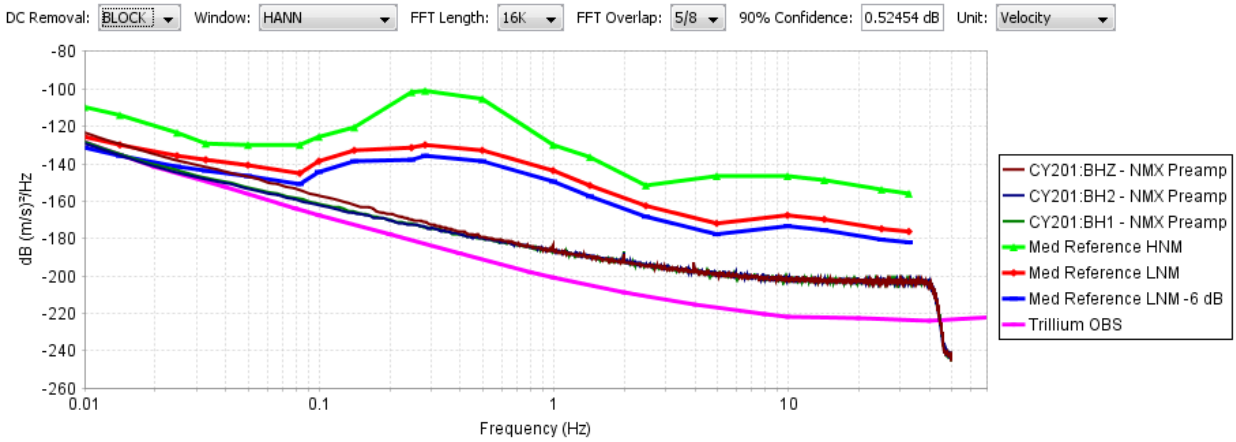


Figure 81 Digitizer #3 Broadband Seismic System Noise

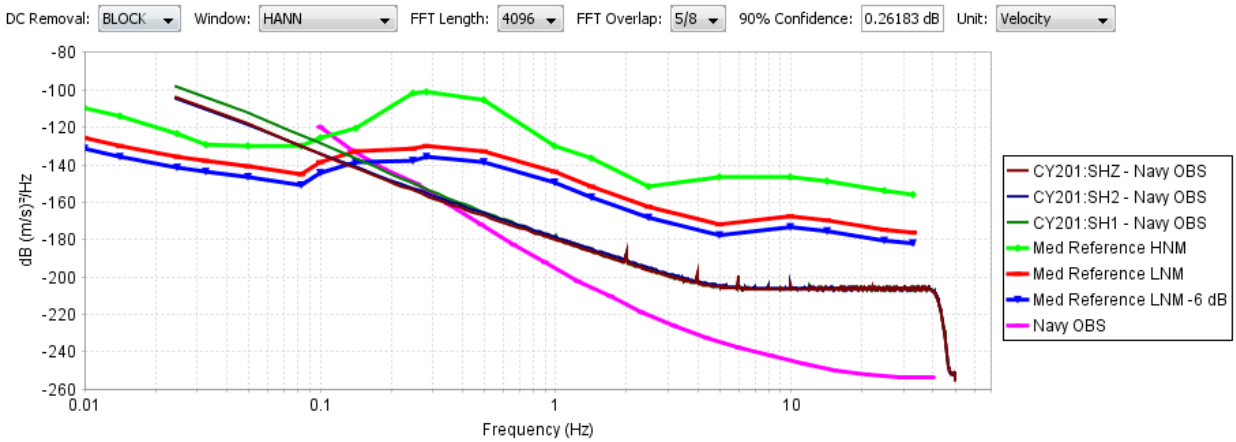


Figure 82 Digitizer #3 Short-period Seismic System Noise

4.8.4 Digitizer # 4

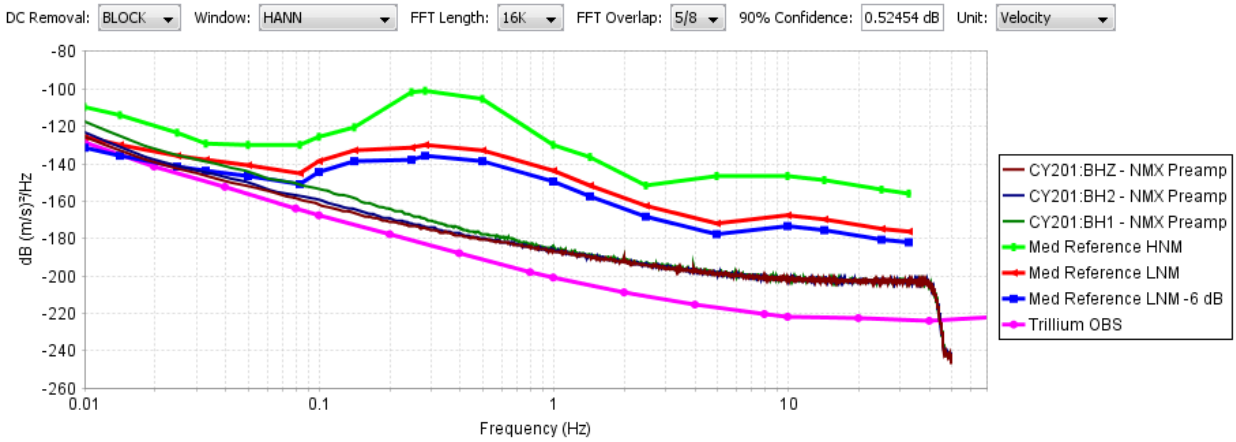


Figure 83 Digitizer #4 Broadband Seismic System Noise

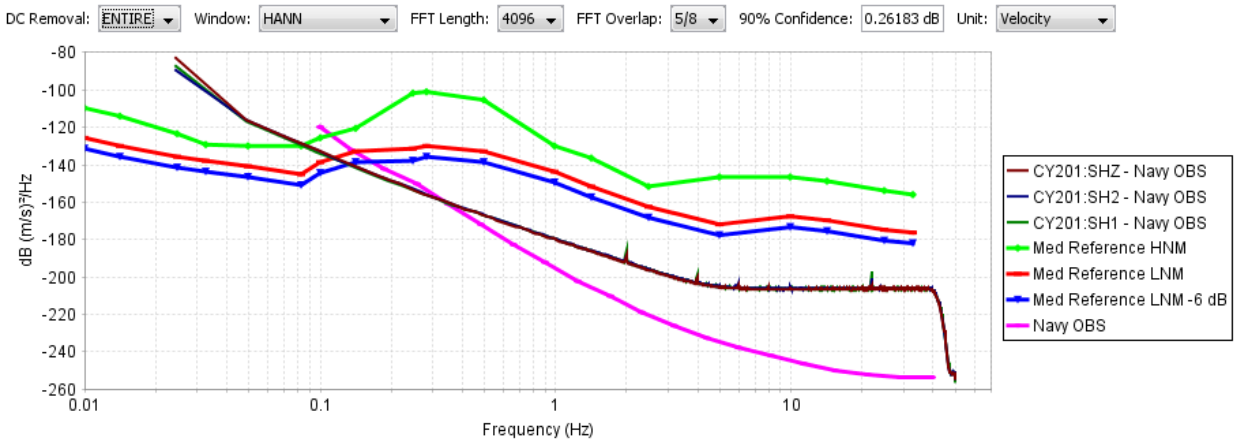


Figure 84 Digitizer #4 Short-period Seismic System Noise

4.8.5 Digitizer # 5

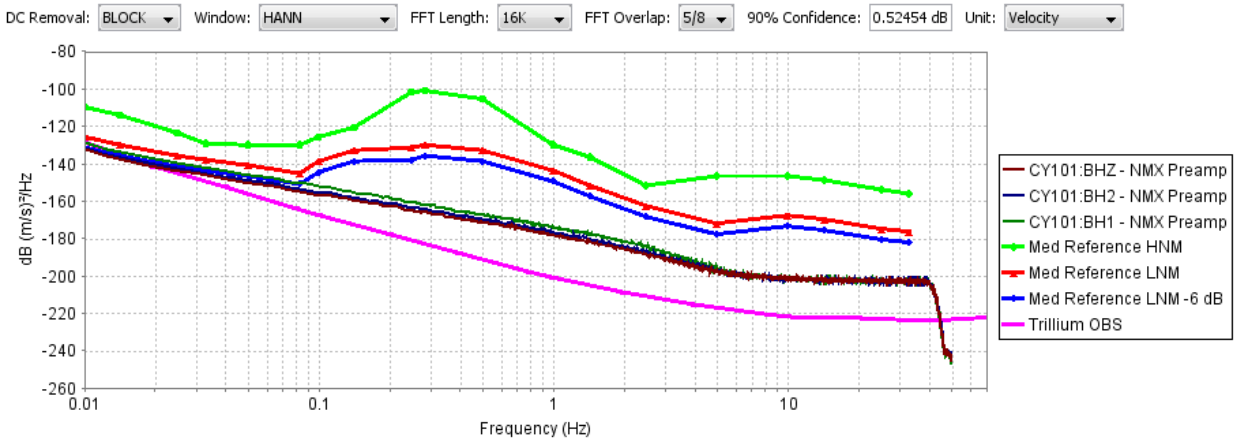


Figure 85 Digitizer #5 Broadband Seismic System Noise

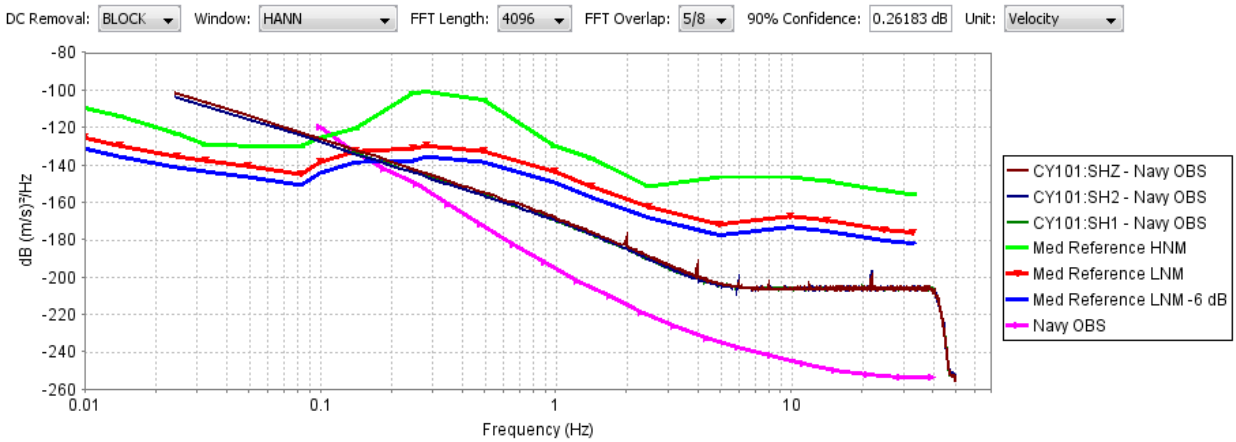


Figure 86 Digitizer #5 Short-period Seismic System Noise

4.8.6 Digitizer # 6

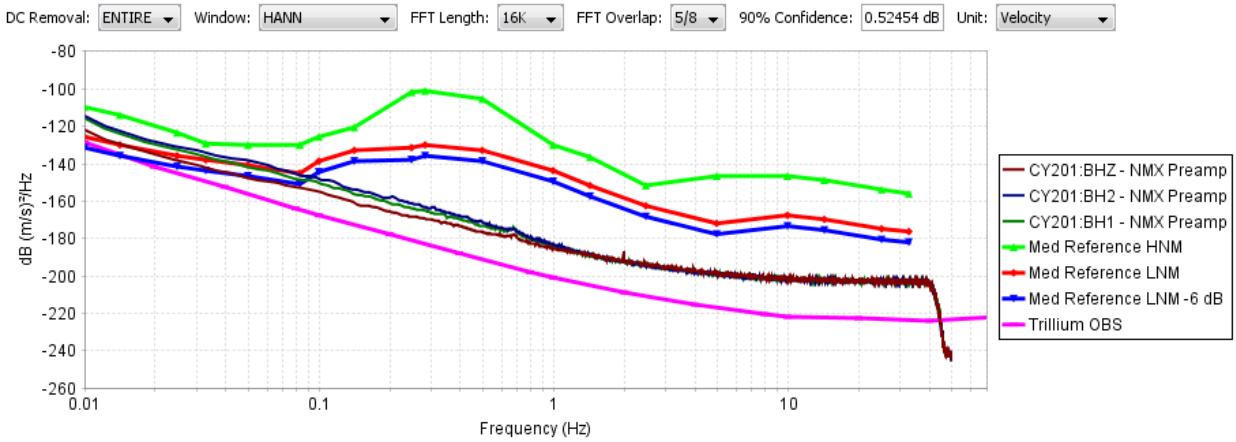


Figure 87 Digitizer #6 Broadband Seismic System Noise

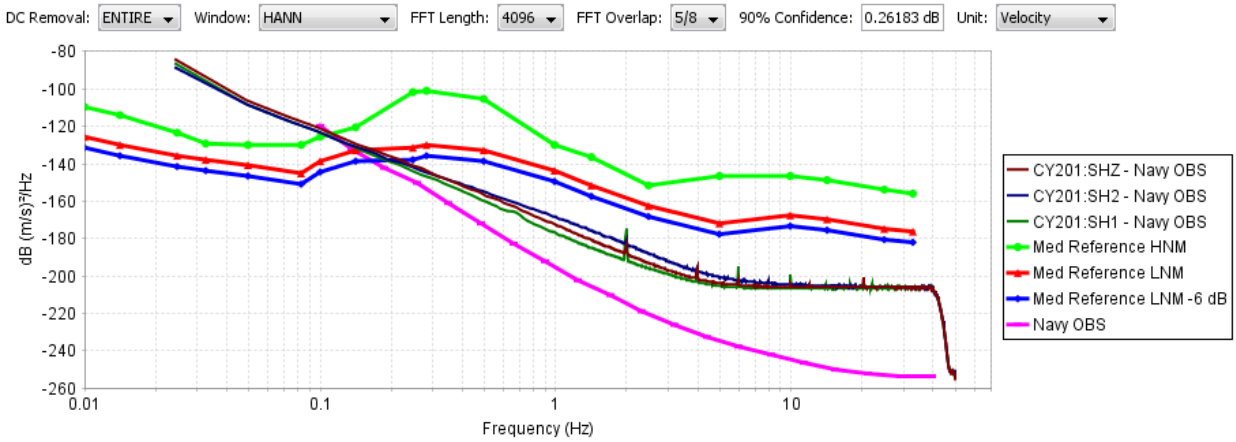


Figure 88 Digitizer #6 Short-period Seismic System Noise

4.8.7 *Digitizer # 7*

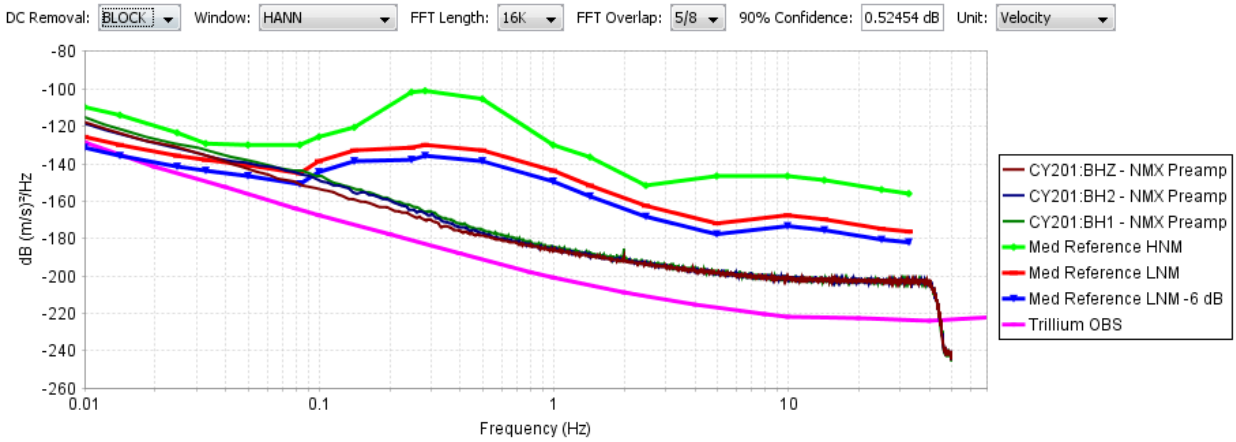


Figure 89 Digitizer #7 Broadband Seismic System Noise

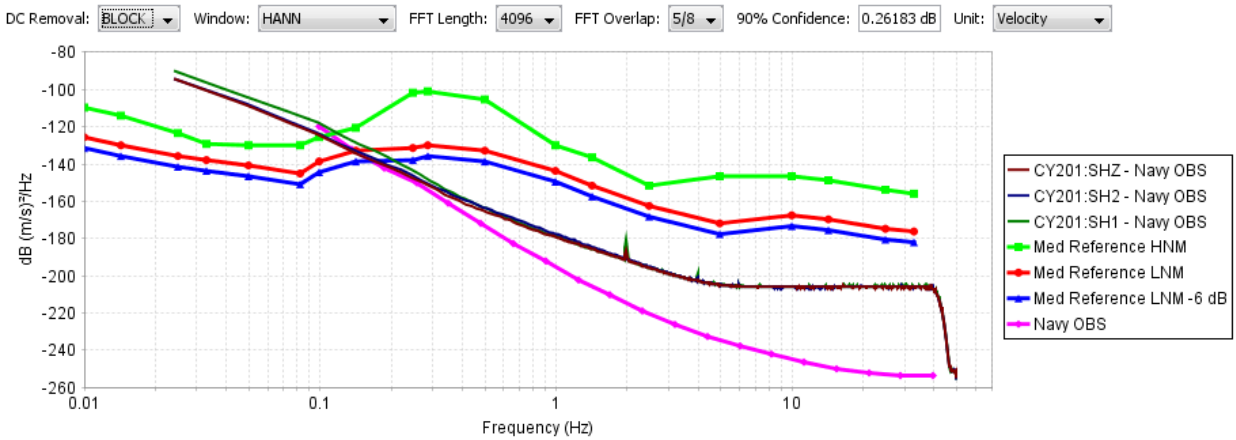


Figure 90 Digitizer #7 Short-period Seismic System Noise

4.8.8 Digitizer # 8

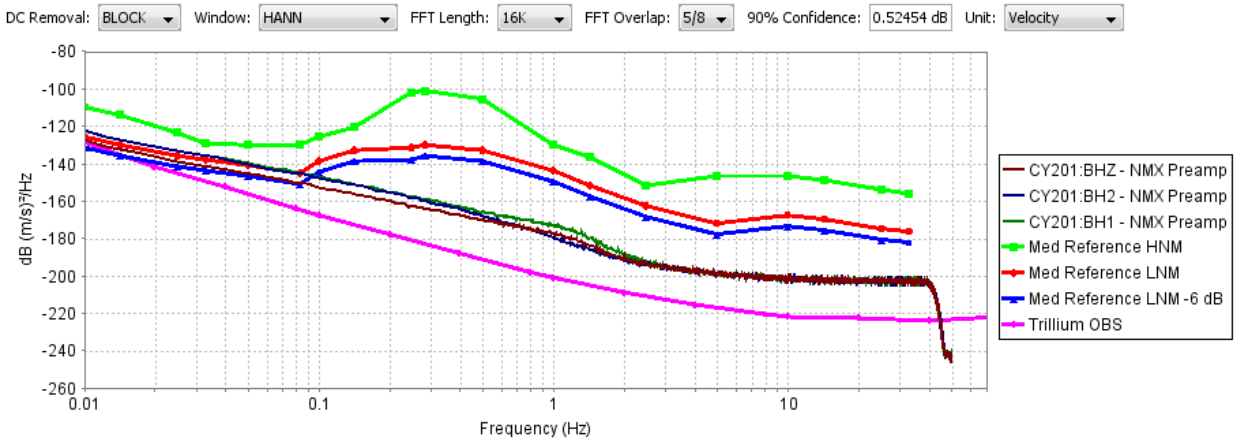


Figure 91 Digitizer #8 Broadband Seismic System Noise

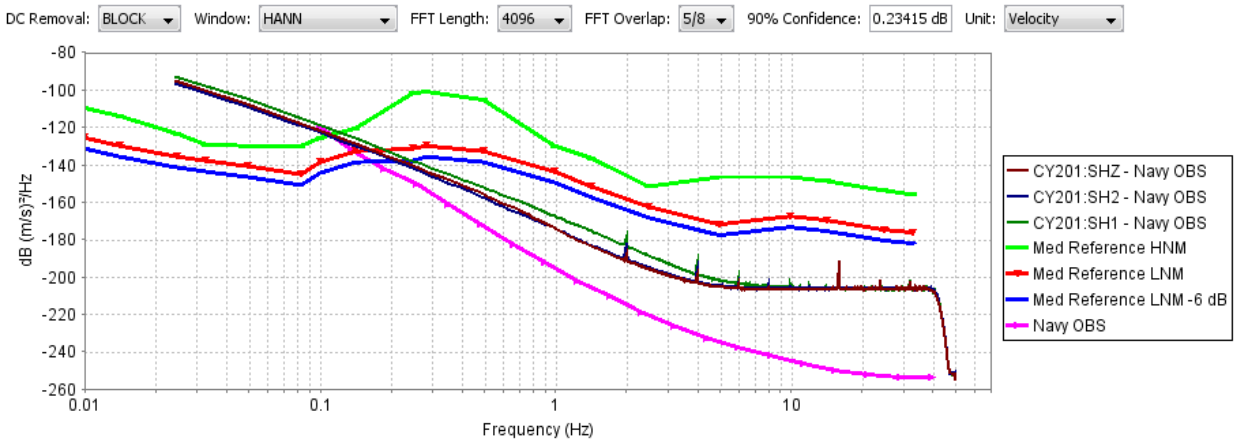


Figure 92 Digitizer #8 Short-period Seismic System Noise

4.8.9 *Digitizer # 9*

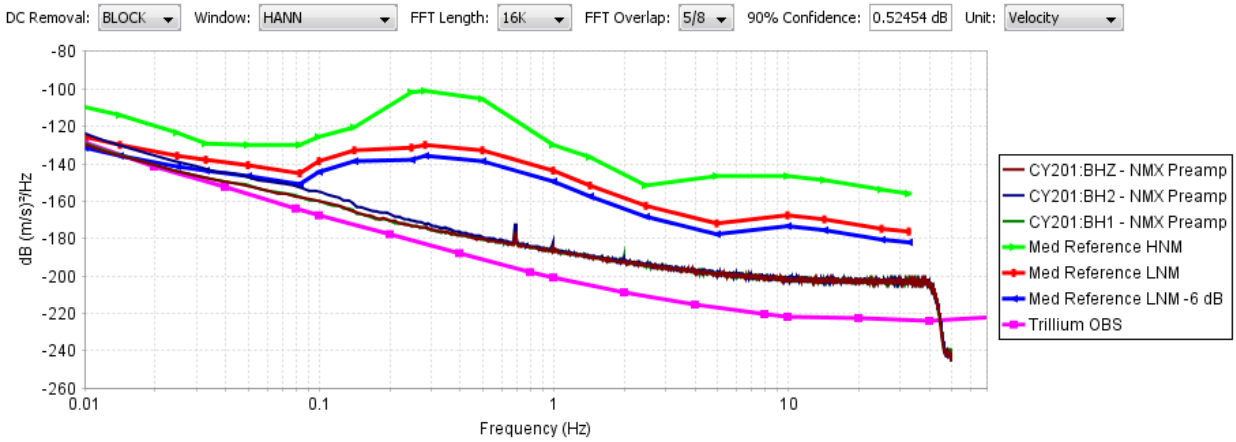


Figure 93 Digitizer #9 Broadband Seismic System Noise

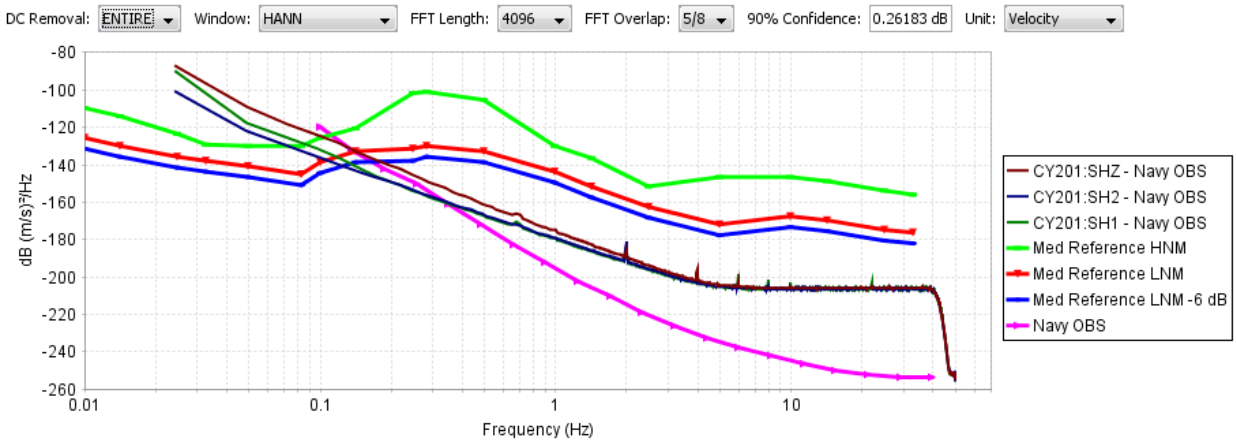


Figure 94 Digitizer #9 Short-period Seismic System Noise

4.8.10 Digitizer # 10

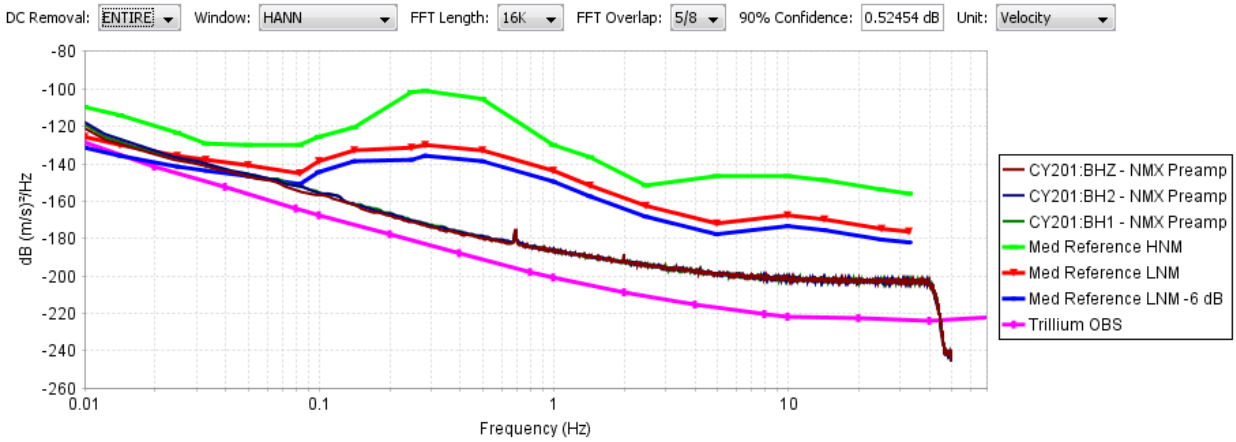


Figure 95 Digitizer #10 Broadband Seismic System Noise

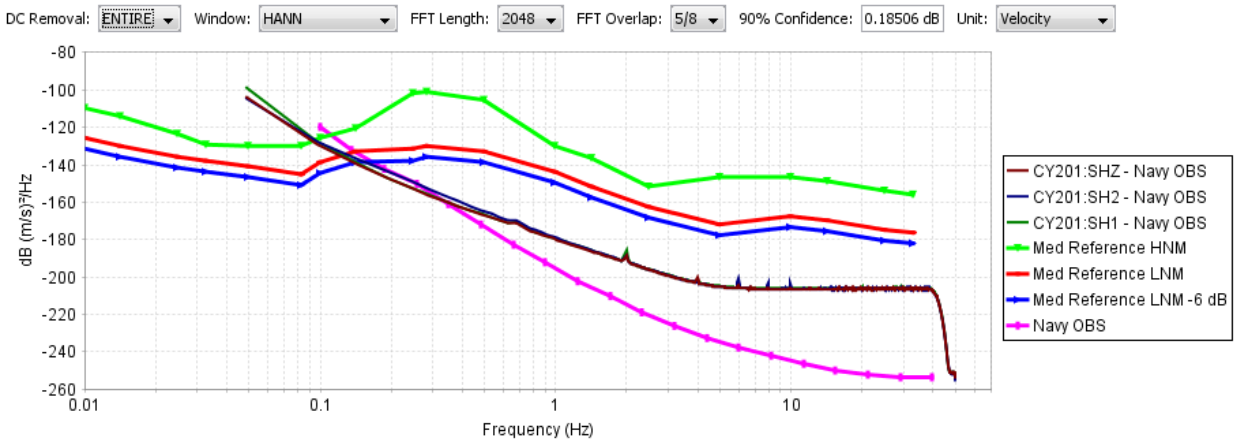


Figure 96 Digitizer #10 Short-period Seismic System Noise

4.8.11 Digitizer # 11

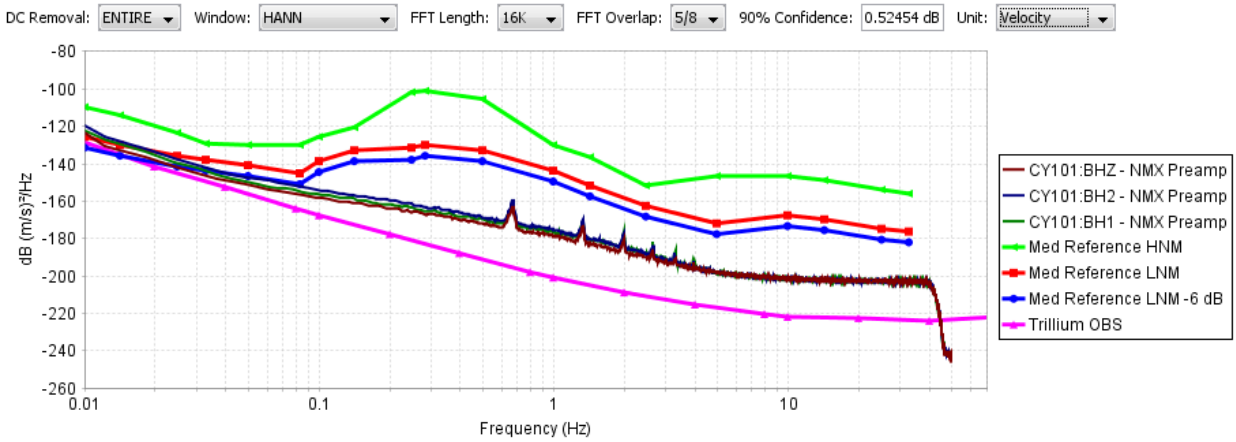


Figure 97 Digitizer #11 Broadband Seismic System Noise

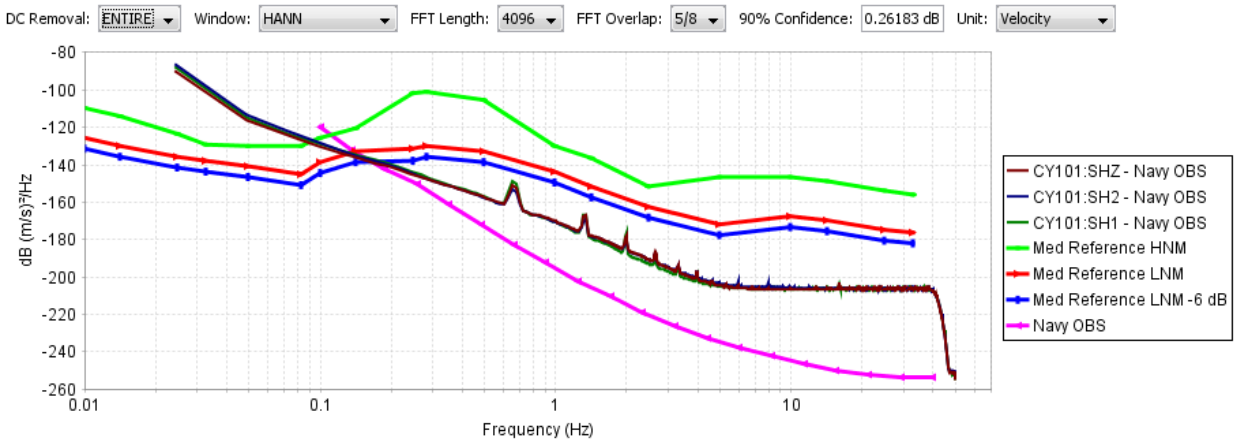


Figure 98 Digitizer #11 Short-period Seismic System Noise

4.8.12 Digitizer # 12

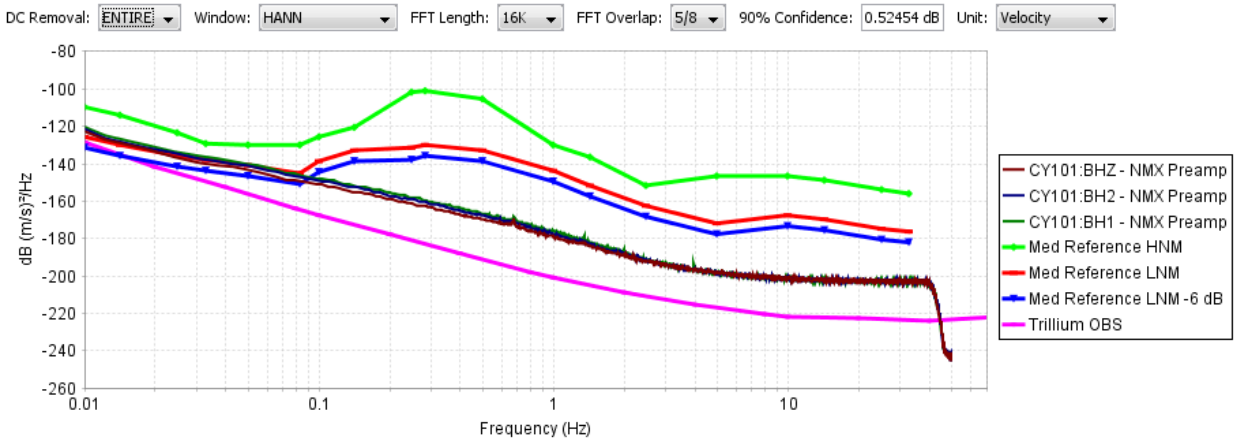


Figure 99 Digitizer #12 Broadband Seismic System Noise

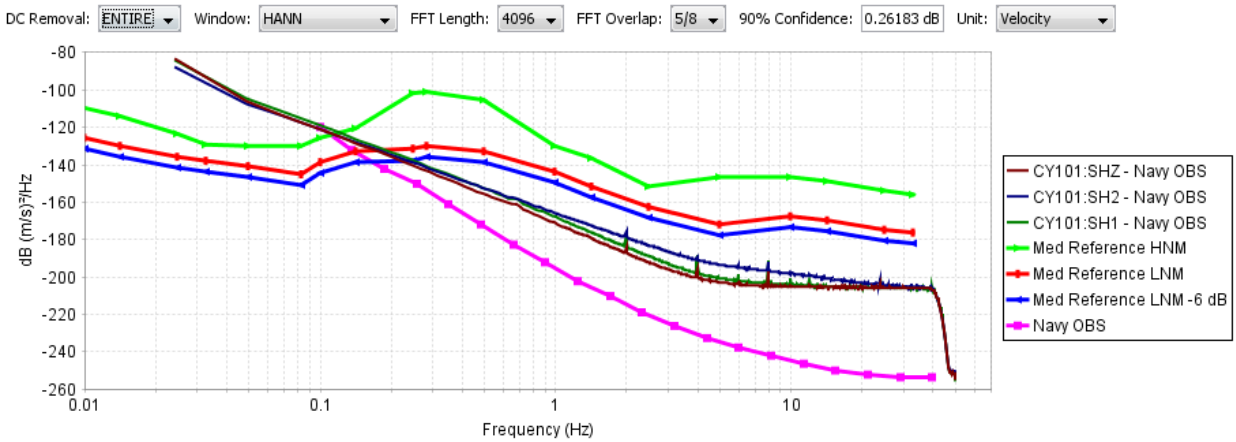


Figure 100 Digitizer #12 Short-period Seismic System Noise

4.8.13 Digitizer # 13

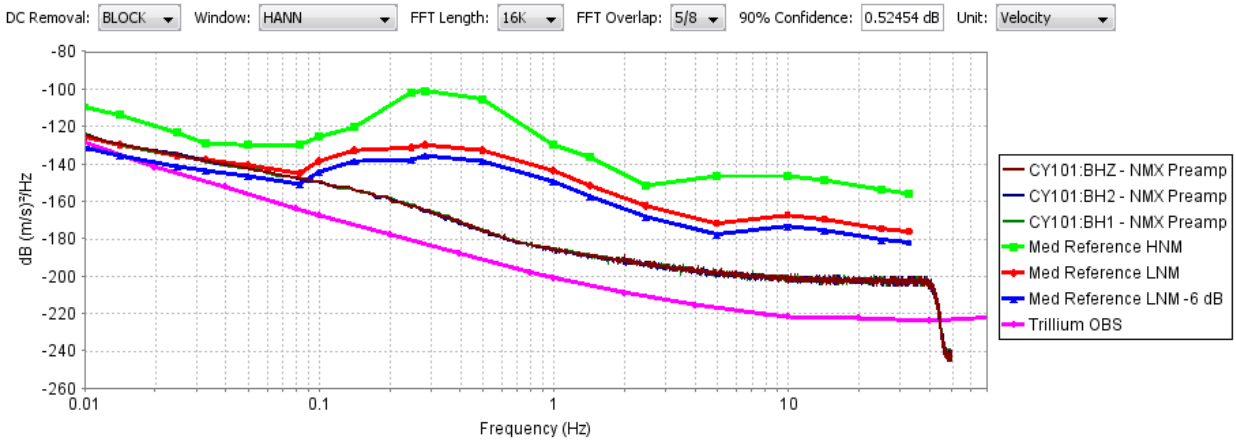


Figure 101 Digitizer #13 Broadband Seismic System Noise

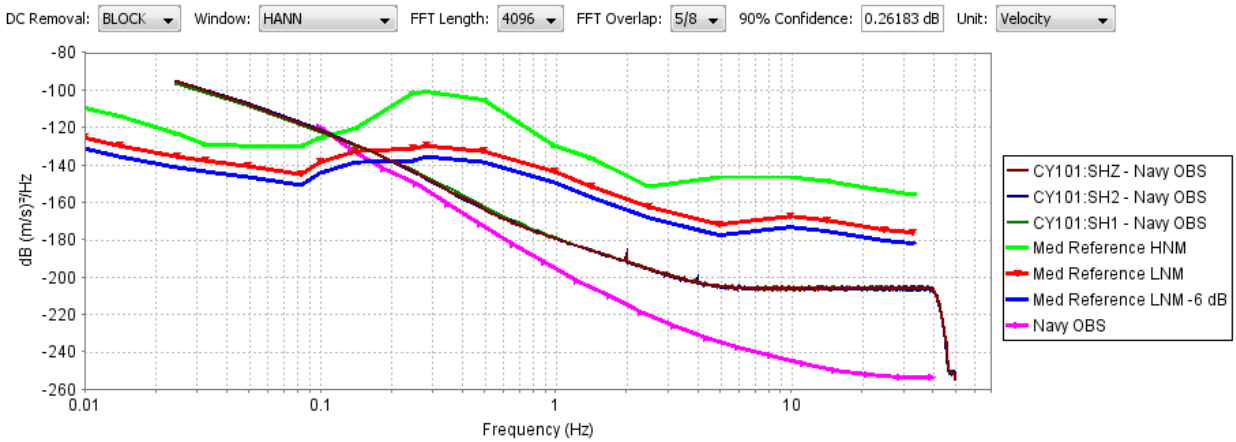


Figure 102 Digitizer #13 Short-period Seismic System Noise

4.8.14 Digitizer # 14

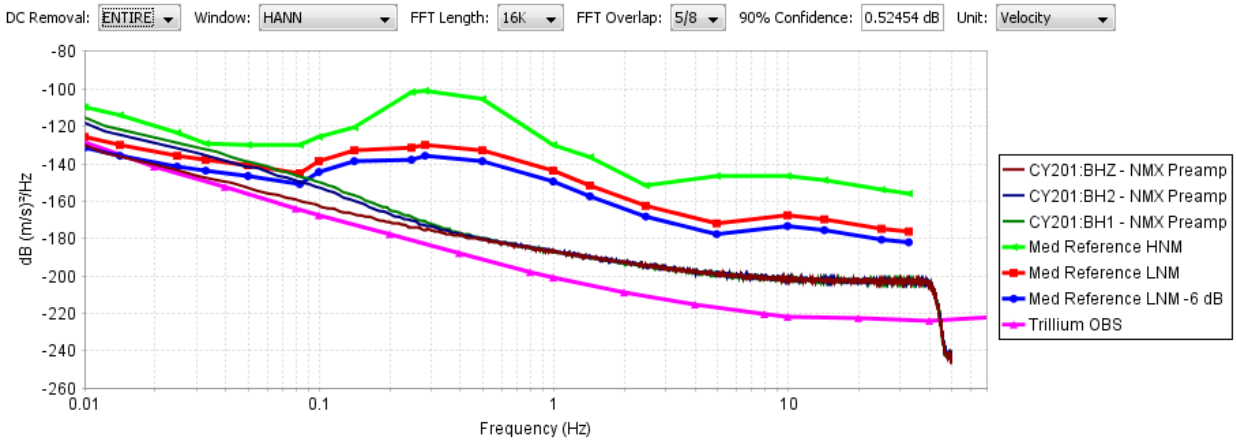


Figure 103 Digitizer #14 Broadband Seismic System Noise

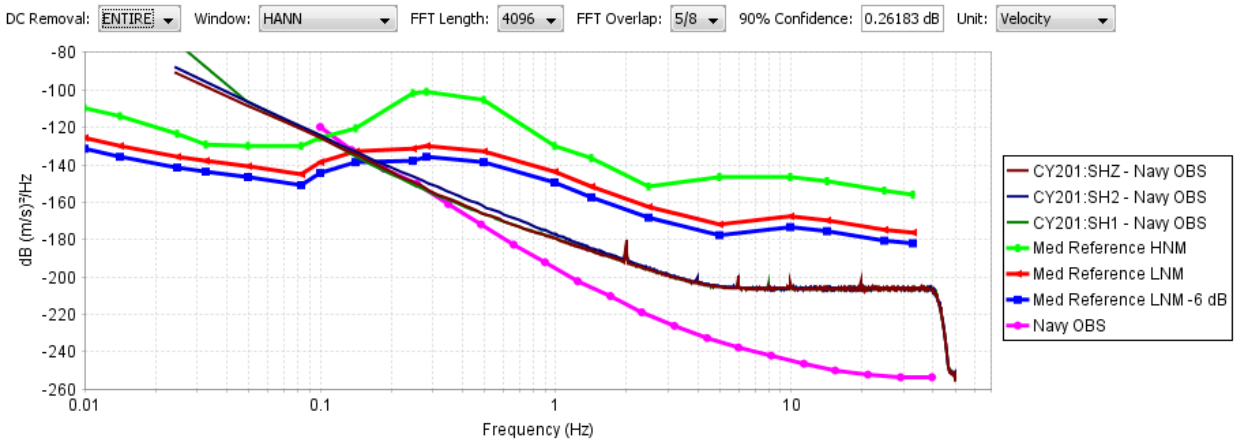


Figure 104 Digitizer #14 Short-period Seismic System Noise

4.8.15 Digitizer # 15

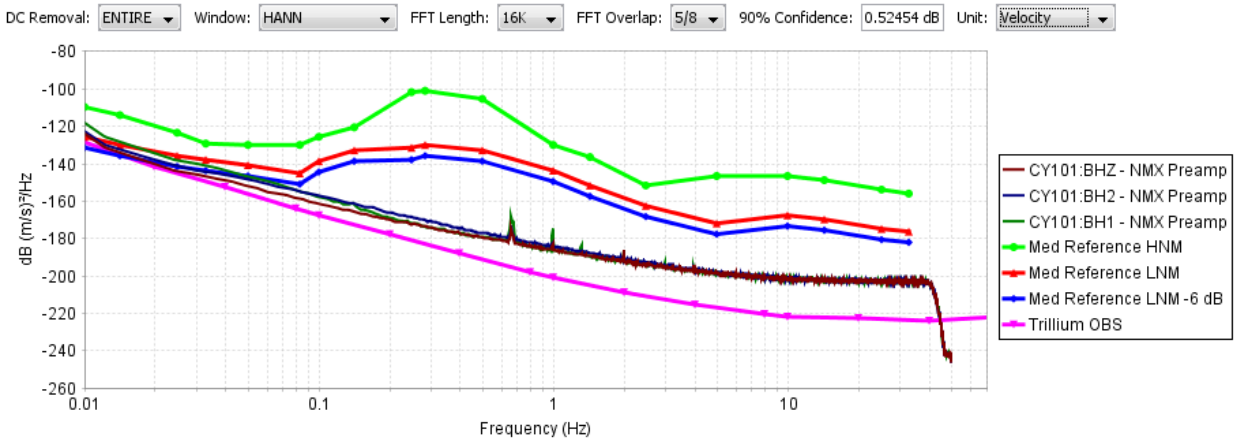


Figure 105 Digitizer #15 Broadband Seismic System Noise

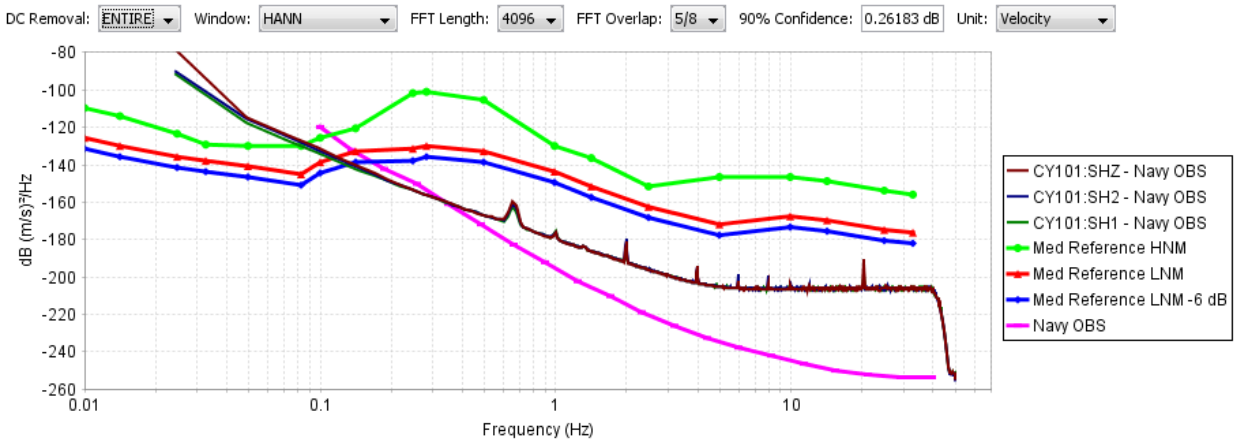


Figure 106 Digitizer #15 Short-period Seismic System Noise

4.8.16 Digitizer # 16

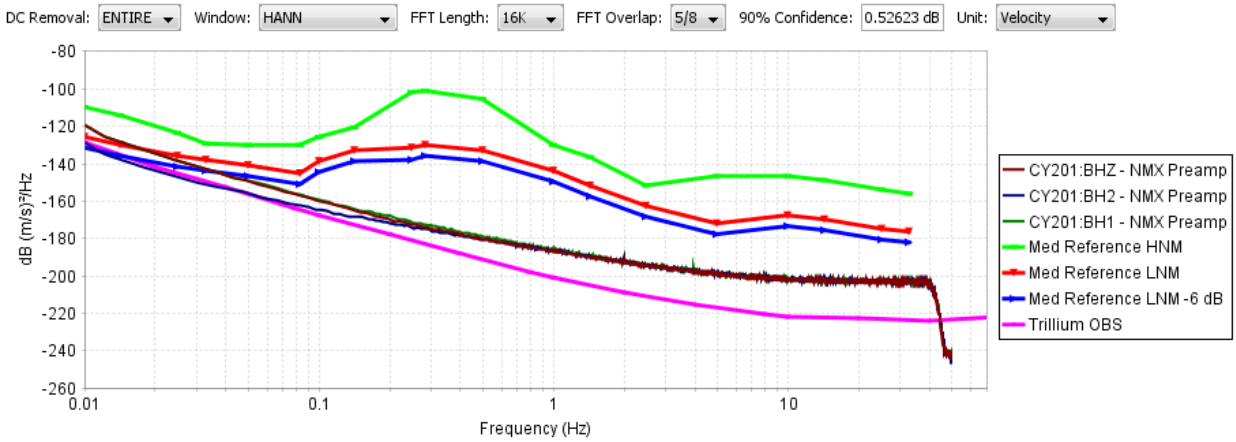


Figure 107 Digitizer #16 Broadband Seismic System Noise

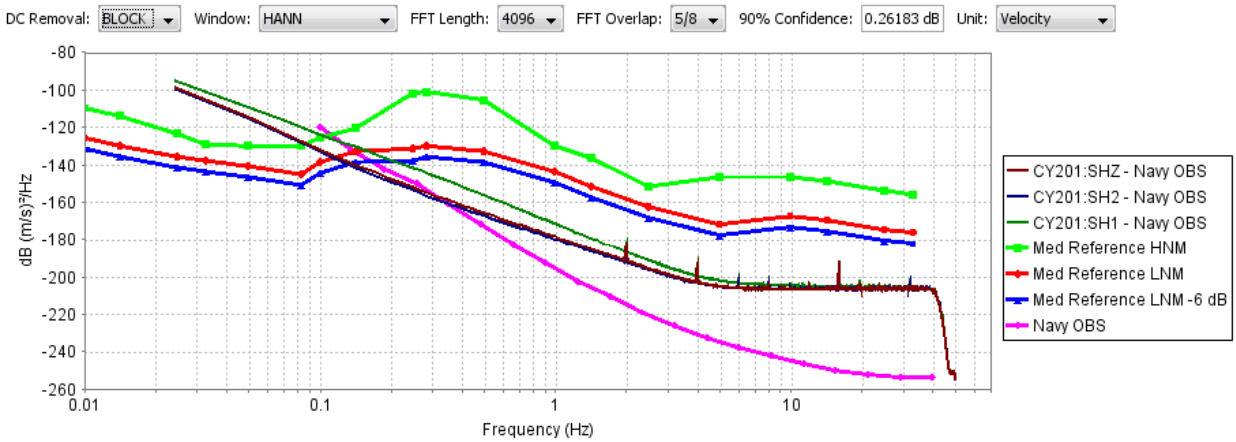


Figure 108 Digitizer #16 Short-period Seismic System Noise

4.8.17 Digitizer # 17

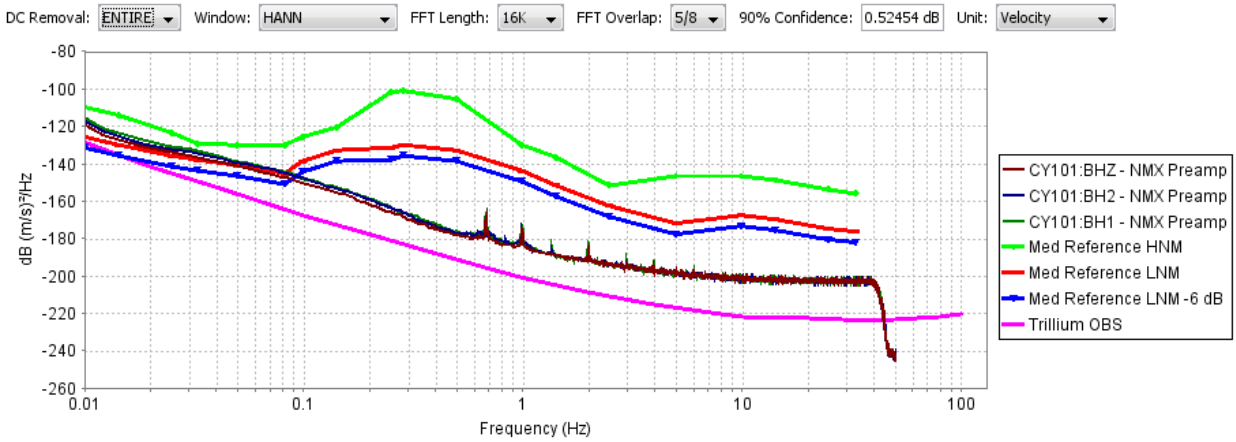


Figure 109 Digitizer #17 Broadband Seismic System Noise

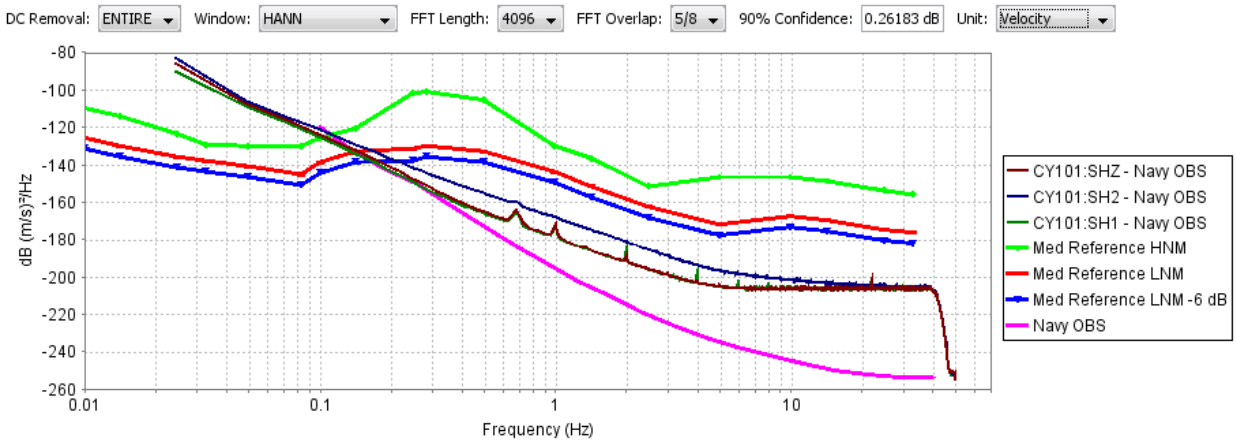


Figure 110 Digitizer #17 Short-period Seismic System Noise

4.8.18 Digitizer # 18

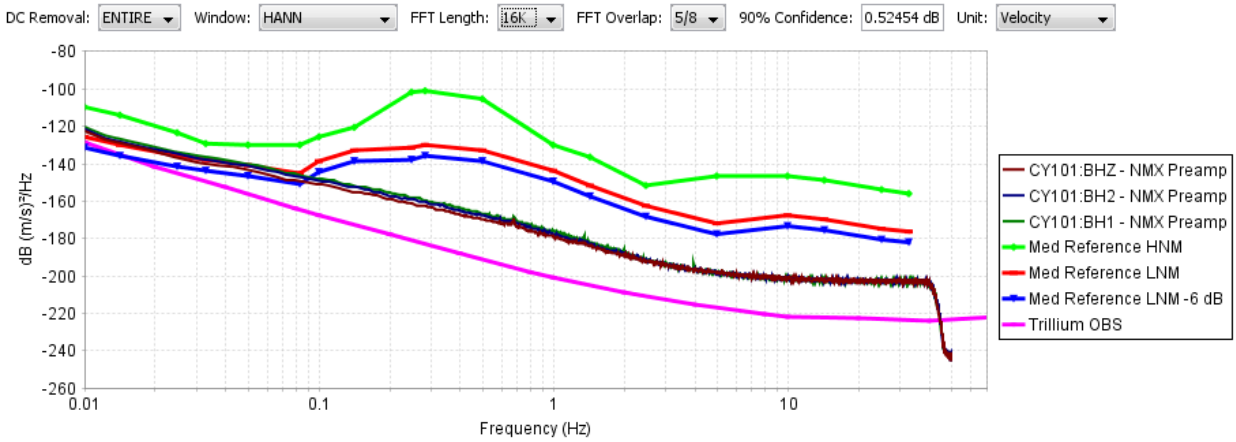


Figure 111 Digitizer #18 Broadband Seismic System Noise

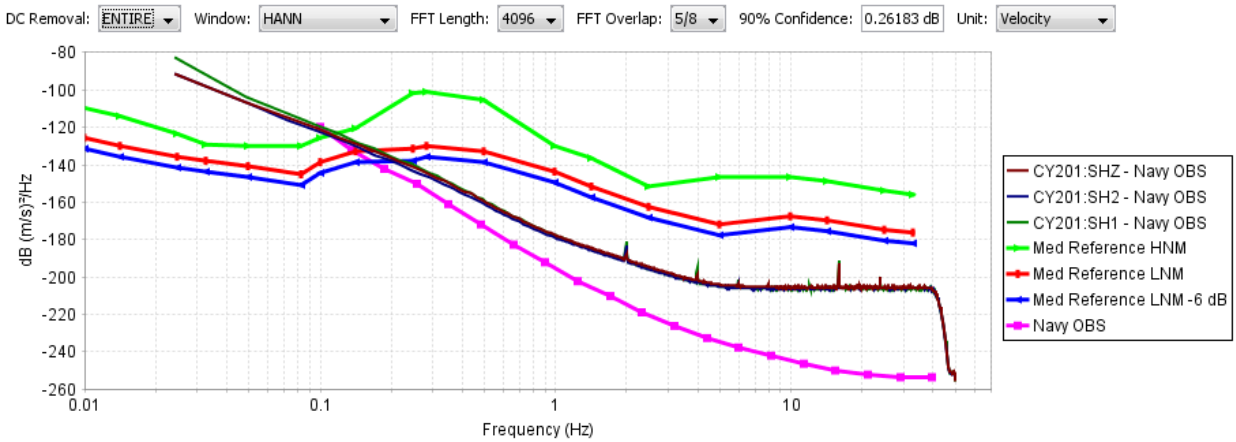


Figure 112 Digitizer #18 Short-period Seismic System Noise

4.9 Response Verification

The amplitude and phase response of each of the digitizer channels was determined by recording a band-limited white noise signal simultaneously on all 6 channels as well as channel 1 of the reference Smart24 digitizer.

The primary channel of the Smart24 was configured to record at 200 Hz so that the anti-alias filter on the Smart24 would not impact the estimate of the SHDAS response. The data from the SHDAS digitizer was up-sampled using a post-processing reconstruction filter that does not affect the amplitude or phase of the recorded signal below the Nyquist frequency of 50 Hz. The results should not be interpreted beyond 50 Hz.

All of the response plots were highly similar across the tested digitizers. A representative set of plots showing the amplitude and phase response are shown below. The amplitude and phase response values versus frequency for the individual digitizers are available in Appendix C: Response Models.

4.9.1 Broadband Channels

Figure 113 Broadband Response Power Spectra

Two channel coherence analysis was performed using the Geotech Smart24 digitizer as the reference. It is observed that the coherence drops off as the signal amplitude on the broad-band channels approaches the self-noise levels of the individual data channels. This drop-off in coherence limits how well the amplitude and phase response may be observed.

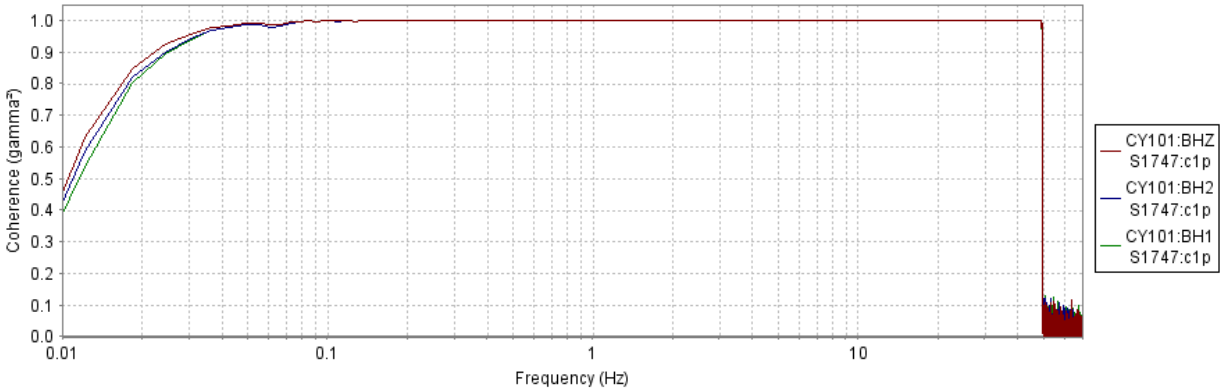


Figure 114 Broadband Coherence

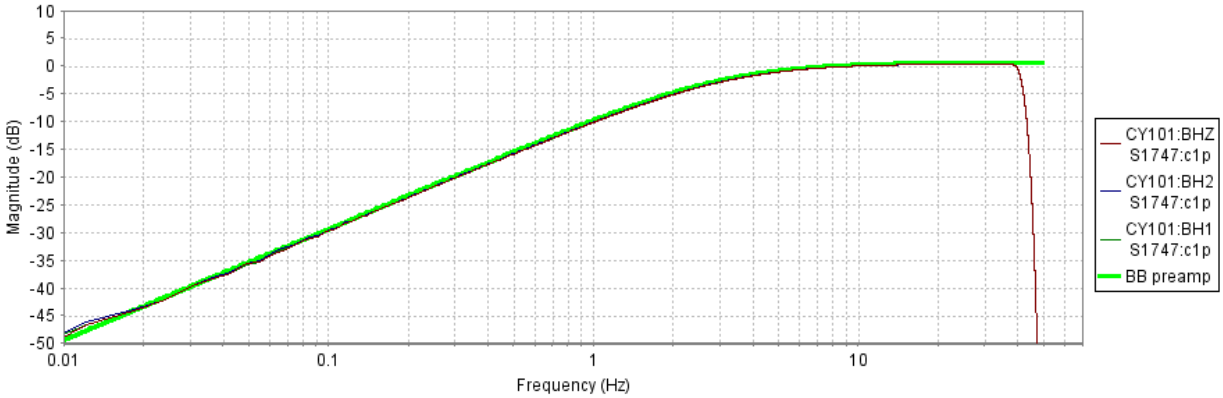


Figure 115 Broadband Amplitude Response

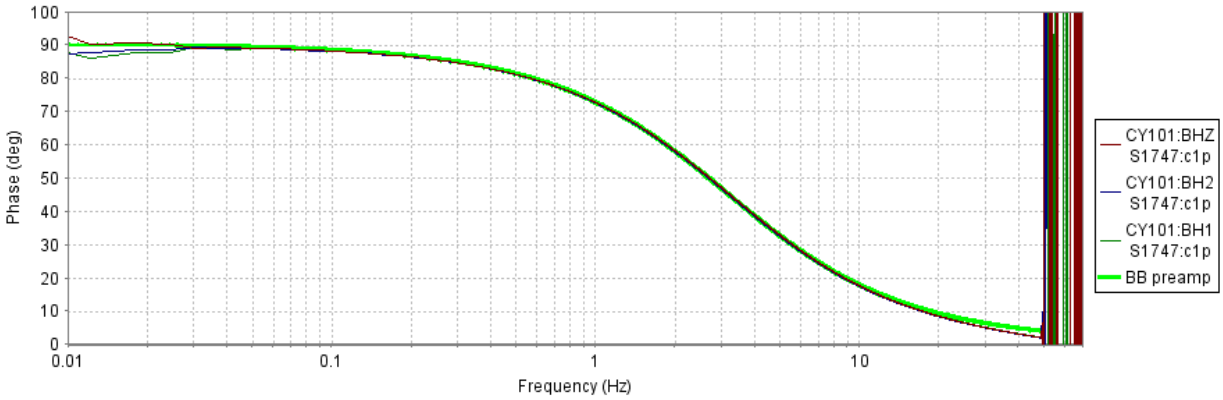


Figure 116 Broadband Phase Response

Correcting the amplitude and phase response for the nominal preamplifier response present on the broad-band channels yield the following amplitude and phase response:

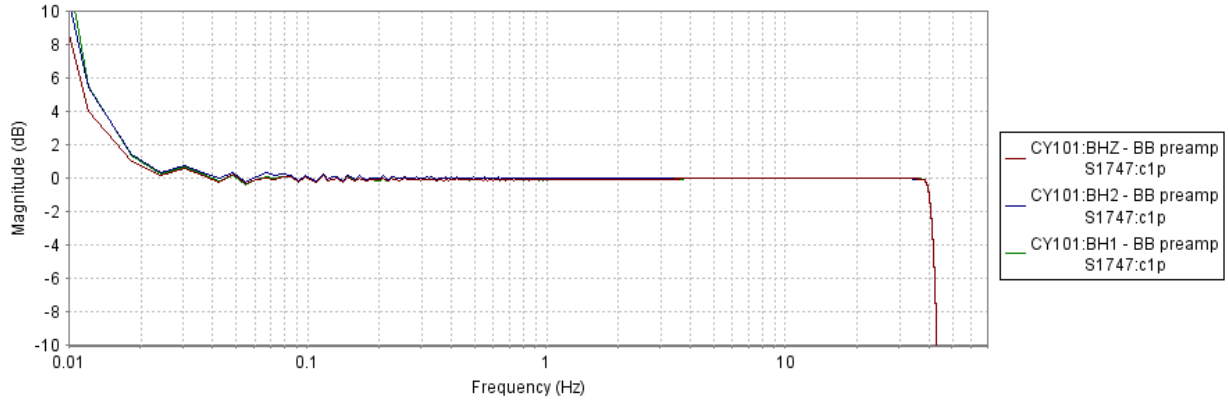


Figure 117 Broadband Amplitude Response – Preamp corrected

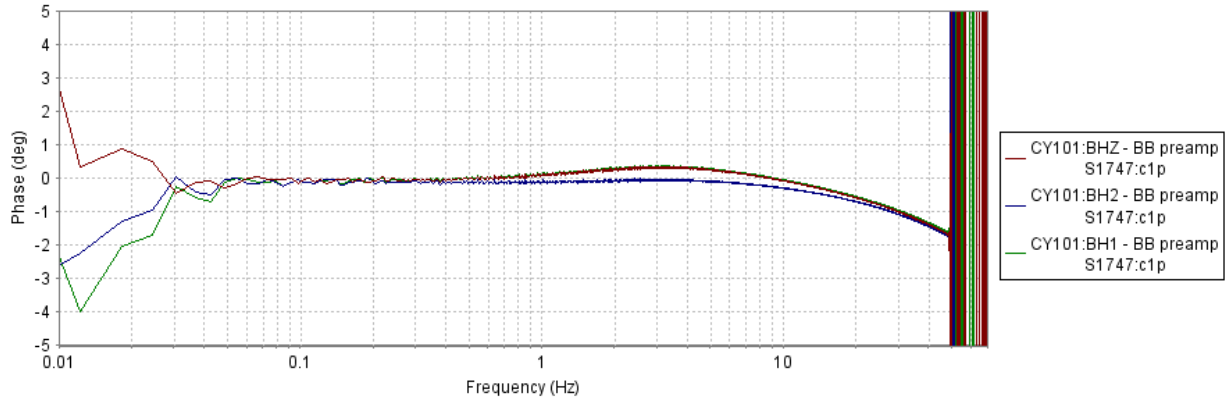


Figure 118 Broadband Phase Response – Preamp corrected

Note that the shown plot of amplitude response has units of dB relative to signal power and not amplitude. Therefore, the dB values should be reduced by a factor of 2 in order to convert them to be relative to amplitude.

It is observed that in all cases for the broad-band channels that they differed across 0.02 – 40 Hz (with the exception of the digitizer anti-alias filter) from the nominal pre-amplifier model by less than 0.25 dB in amplitude and 2 degrees in phase. The roll-off of the digitizer filter does result in an approximate -0.45 dB decrease in amplitude at 40 Hz.

The observed roll-off in the phase response is due to a constant time offset of approximately 100 microseconds introduced by the Shore-side SNIT.

4.9.2 *Short Period Channels*

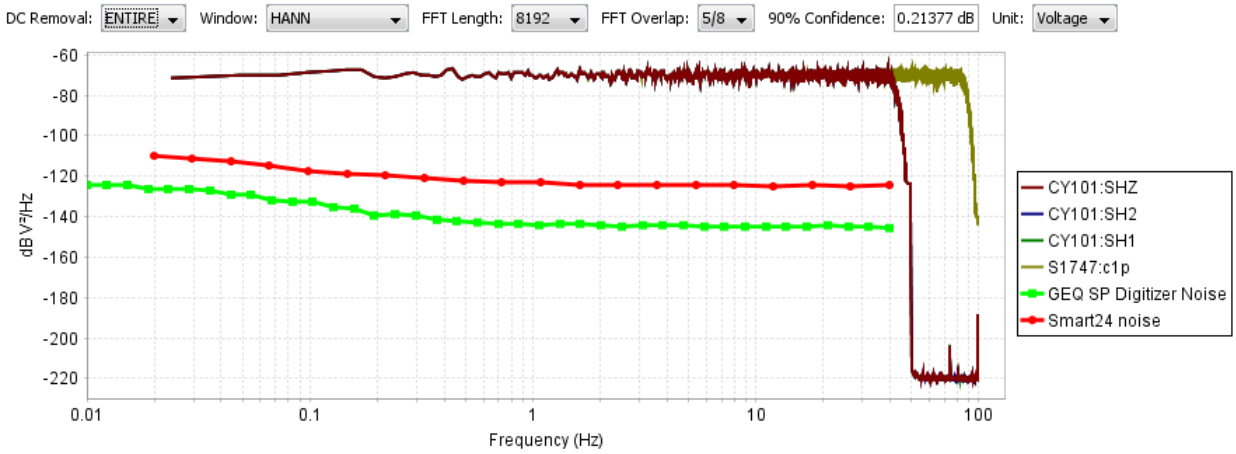


Figure 119 Short-period Power Spectra

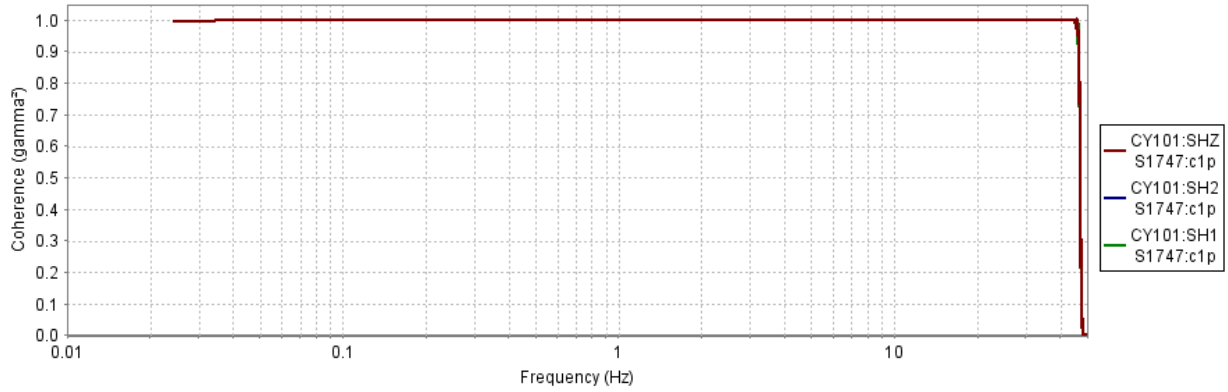


Figure 120 Short-period Coherence

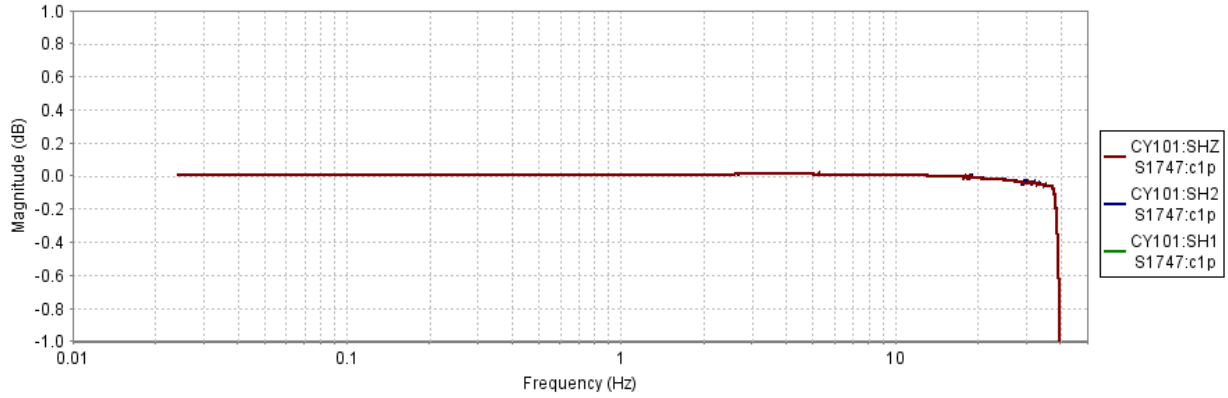


Figure 121 Short-period Amplitude Response

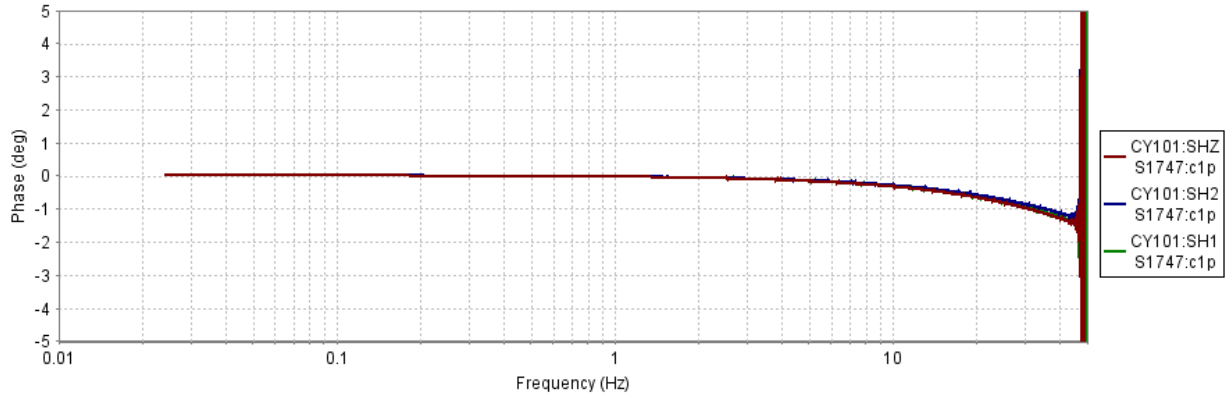


Figure 122 Short-period Phase Response

Note that the shown plot of amplitude response has units of dB relative to signal power and not amplitude. Therefore, the dB values should be reduced by a factor of 2 in order to convert them to be relative to amplitude.

It is observed that in all cases for the short-period channels that they differed across 1 – 40 Hz (with the exception of the digitizer anti-alias filter) from the nominal pre-amplifier model by less than 0.01 dB in amplitude and 1.5 degrees in phase. The roll-off of the digitizer filter does result in an approximate -0.45 dB decrease in amplitude at 40 Hz.

The observed roll-off in the phase response is due to a constant time offset of approximately 100 microseconds introduced by the Shore-side SNIT.

4.9.3 Response Time Offset

All of the channels have response characteristics that are consistent with the nominal response models provided. However, the differences in the phase responses that were observed are attributable to the single prototype shore-side SNIT that is performing time-stamping of the data.

A constant time offset in the time series will result in a linear phase response versus frequency. In such a case, the slope of the phase response is proportional to the time offset. As may be seen in the example plots below, the phase response is a straight line across approximately 10 – 48 Hz for the broadband channels and 0 – 48 Hz for the short-period channels.

On the broad-band channels, the phase response was corrected for the nominal response of the preamplifier, therefore the characteristics below 10 Hz are due to a slight miss-match between the nominal and actual response characteristics of the broad-band preamplifier.

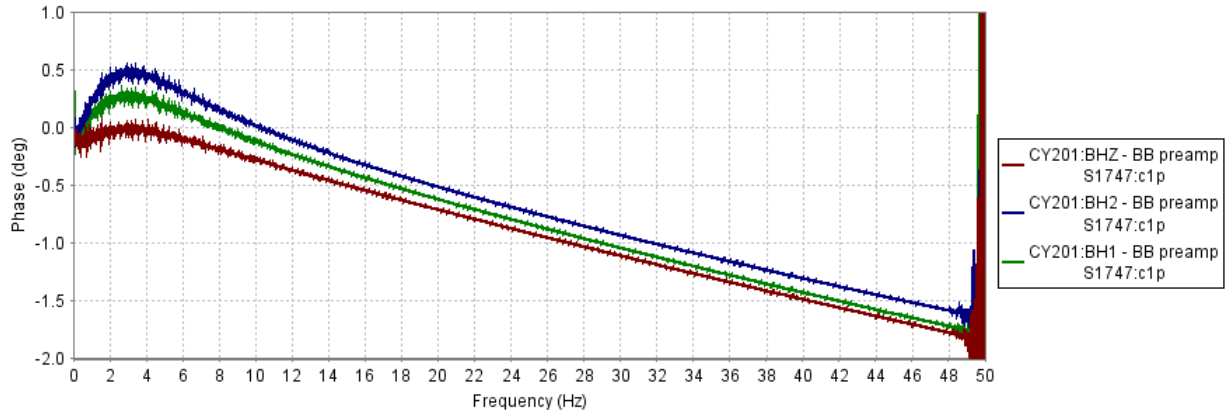


Figure 123 Broad-band linear phase response

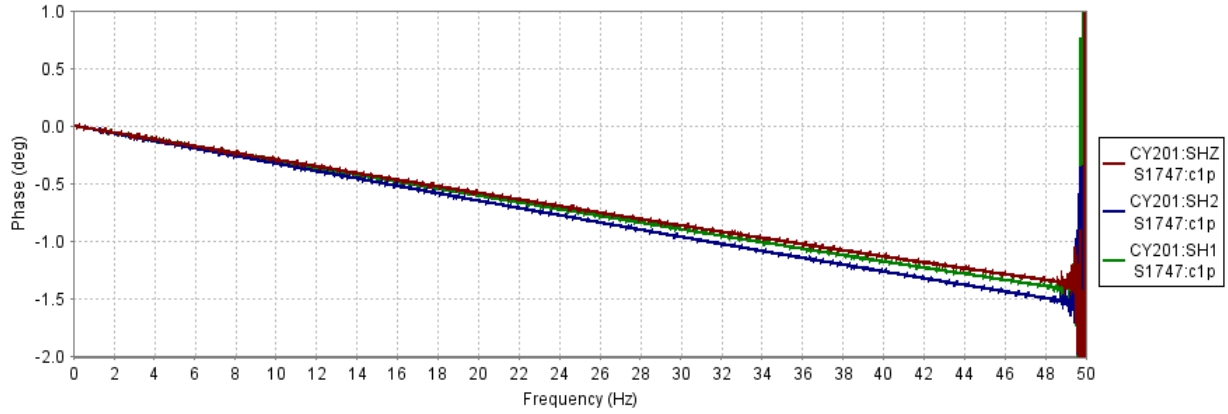


Figure 124 Short-period linear phase response

The estimated time offset for each digitizer channel was estimated by determining the slope of the phase response over 10 – 48 Hz.

Table 15 SHDAS digitizer response time offset

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
# 1	-99.94 us	-76.14 us	-89.42 us	-80.00 us	-89.12 us	-89.12 us
# 2	-125.78 us	-115.00 us	-117.15 us	-107.73 us	-79.73 us	-88.09 us
# 3	-108.32 us	-114.55 us	-107.73 us	-79.84 us	-80.82 us	-89.01 us
# 4	-100.83 us	-80.60 us	-98.25 us	-79.22 us	-75.11 us	-88.87 us
# 5	-85.01 us	-96.55 us	-92.06 us	-91.71 us	-73.90 us	-87.28 us
# 6	-93.79 us	-100.45 us	-82.74 us	-77.77 us	-71.98 us	-90.20 us
# 7	-409.35 us	-406.72 us	-420.59 us	-402.78 us	-405.12 us	-406.58 us
# 8	-99.94 us	-76.14 us	-76.14us	-80.00us	-89.16us	-83.03 us
# 9	-97.72 us	-82.49 us	-107.76 us	-84.27 us	-86.09 us	-85.22 us
# 10	-96.94 us	-94.50 us	-77.77 us	-83.96 us	-87.01 us	-83.72 us
# 11	-73.11 us	-86.57 us	-90.34 us	-82.01 us	-74.51 us	-84.40 us
# 12	-1491.66 us	-1480.99 us	-1470.57 us	-1471.41 us	-1472.10 us	-1474.51 us
# 13	-84.69 us	-97.97 us	-80.18 us	-80.30 us	-93.38 us	-79.84 us
# 14	-185.31 us	-202.08 us	-203.08 us	-190.62 us	-193.62 us	-187.26 us
# 15	-191.70 us	-207.66 us	-200.38 us	-189.62 us	-186.10 us	-183.60 us
# 16	-559.07 us	-564.13 us	-558.73 us	-545.14 us	-533.26 us	-544.07 us
# 17	-382.41 us	-379.36 us	-371.24 us	-354.99 us	-357.65 us	-349.23 us
# 18	-1479.46 us	-1471.13 us	-1481.67 us	-1473.49 us	-1481.29 us	-1480.50 us

The differences in the time offset from one digitizer to the next is attributable to the variable performance of the prototype SNIT used for production testing. It was found over the course of testing digitizers that the pre-production SNIT may drift off of its GPS lock on occasion and need to be reset.

What is of interest is that individual channels for a given digitizer were all very similar to one another. The typical spread of channel-to-channel time offsets was within 20 – 30 microseconds with the worst case being within 46 microseconds on digitizer #2.

The values within this table were also found to be consistent with the results obtained when performing the 10 Hz sinusoid timing tests while the SNIT was in the same state. Resetting the SNIT and re-running the timing tests would generally yield a timing offset on the order of 100 microseconds.

Based upon these results, it is expected that the digitizer electronics within the pressure vessel is able to reliably digitize and transmit sensor data back to the shore-side equipment with less than approximately 100 microseconds of timing offset, provided the shore-side SNIB and SNIT are operating properly.

4.10 Passband

The low and high frequency passband limits are determined by identifying low and high frequencies at which each digitizer channel's amplitude response is 3 dB in power, below the sensitivity at 10 Hz.

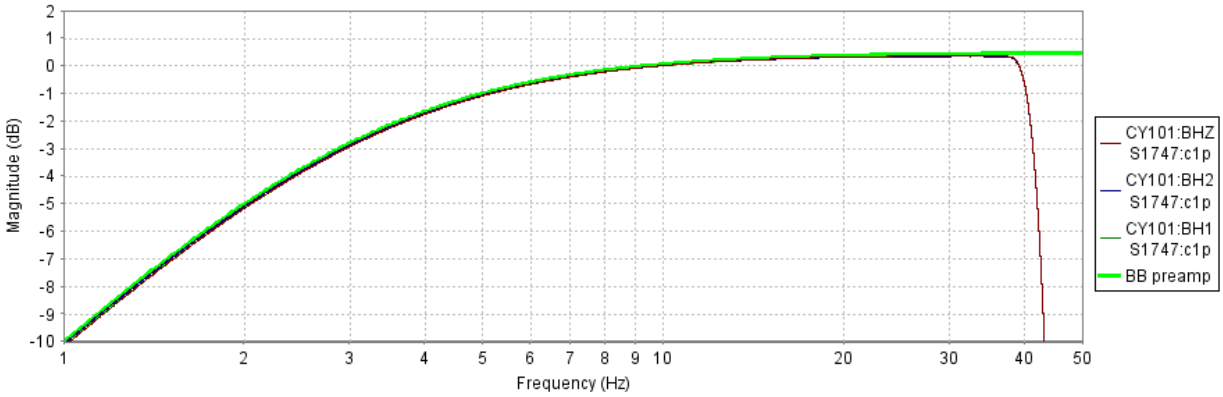


Figure 125 Typical Broadband Power Response

The nominal response model for the broadband channels has a low frequency corner of 2.92 Hz. Frequency limits are rounded to provide 2 significant digits after the decimal point.

Table 16 Digitizer Broadband Passband

Digitizer	BHZ – Low	BHZ – High	BH2 – Low	BH2 – High	BH1 – Low	BH1 – High
# 1	2.93 Hz	41.41 Hz	2.97 Hz	41.41 Hz	2.95 Hz	41.41 Hz
# 2	2.88 Hz	41.40 Hz	2.89 Hz	41.40 Hz	2.89 Hz	41.40 Hz
# 3	2.90 Hz	41.41 Hz	2.89 Hz	41.40 Hz	2.89 Hz	41.40 Hz
# 4	2.92 Hz	41.41 Hz	2.97 Hz	41.41 Hz	2.94 Hz	41.41 Hz
# 5	2.96 Hz	41.41 Hz	2.93 Hz	41.41 Hz	2.95 Hz	41.41 Hz
# 6	2.94 Hz	41.41 Hz	2.93 Hz	41.41 Hz	2.96 Hz	41.41 Hz
# 7	2.91 Hz	41.42 Hz	2.94 Hz	41.42 Hz	2.92 Hz	41.41 Hz
# 8	2.93 Hz	41.41 Hz	2.93 Hz	41.41 Hz	2.96 Hz	41.41 Hz
# 9	2.92 Hz	41.41 Hz	2.96 Hz	41.41 Hz	2.90 Hz	41.41 Hz
# 10	2.92 Hz	41.42 Hz	2.91 Hz	41.42 Hz	2.98 Hz	41.42 Hz
# 11	2.96 Hz	41.42 Hz	2.94 Hz	41.42 Hz	2.92 Hz	41.42 Hz
# 12	2.93 Hz	41.41 Hz	2.94 Hz	41.41 Hz	2.97 Hz	41.41 Hz
# 13	2.96 Hz	41.41 Hz	2.93 Hz	41.41 Hz	2.96 Hz	41.41 Hz
# 14	2.96 Hz	41.41 Hz	2.94 Hz	41.41 Hz	2.94 Hz	41.41 Hz
# 15	2.94 Hz	41.41 Hz	2.92 Hz	41.41 Hz	2.93 Hz	41.41 Hz
# 16	2.91 Hz	41.41 Hz	2.91 Hz	41.41 Hz	2.91 Hz	41.41 Hz
# 17	2.90 Hz	41.40 Hz	2.90 Hz	41.40 Hz	2.90 Hz	41.41 Hz
# 18	2.95 Hz	41.41 Hz	2.96 Hz	41.41 Hz	2.93 Hz	41.41 Hz

The broad-band channels all exhibited a lower limit of their passband between 2.88 and 2.98 Hz and an upper limit of their pass-band between 41.40 and 41.42 Hz. The lower end of the pass-band is due to the filter implemented on the preamplifier and the upper end of the pass-band is due to the anti-alias filter on the digitizer.

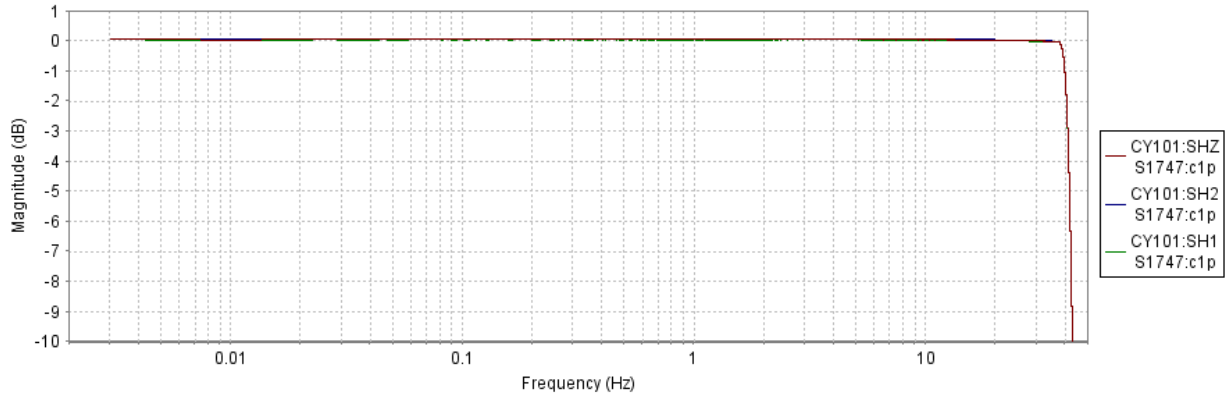


Figure 126 Typical Short-period Power Response

The short-period channels are expected to have a flat response down to 0 Hz. Frequency limits are rounded to provide 2 significant digits after the decimal point.

Table 17 Digitizer Short-period Passband

Digitizer	SHZ – Low	SHZ – High	SH2 – Low	SH2 – High	SH1 – Low	SH1 - High
# 1	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 2	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 3	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 4	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 5	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 6	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 7	0 Hz	41.25 Hz	0 Hz	41.25 Hz	0 Hz	41.25 Hz
# 8	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 9	0 Hz	41.25 Hz	0 Hz	41.25 Hz	0 Hz	41.26 Hz
# 10	0 Hz	41.25 Hz	0 Hz	41.25 Hz	0 Hz	41.25 Hz
# 11	0 Hz	41.25 Hz	0 Hz	41.25 Hz	0 Hz	41.25 Hz
# 12	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 13	0 Hz	41.25 Hz	0 Hz	41.26 Hz	0 Hz	41.25 Hz
# 14	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 15	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 16	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 17	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz
# 18	0 Hz	41.24 Hz	0 Hz	41.24 Hz	0 Hz	41.24 Hz

The short period channels were verified to have a passband that extends down to 0 Hz through a combination of the observed amplitude response from the measurement of a white noise signal at frequencies below 0.02 Hz and the measurement of the channel bit-weight using a DC calibration signal in section 2.3.2 Sensitivity.

The short period channels all exhibited an upper limit of their pass-band between 41.24 and 41.26 Hz which is due to the anti-alias filter on the digitizer.

4.11 Linearity

The linearity of each digitizer channel was measured by recording an ultra-low distortion sinusoid at 6.28 Hz and 10% of full scale on each of the digitizer channels. It was determined in an earlier phase of qualification testing that the signal could be recorded in parallel on each of the banks of broadband and short-period channels simultaneously. The value of 6.28 Hz was chosen to be within the flat portion of the passband, near the calibration frequency of 10 Hz, and to allow sufficient room within the recording passband to be able to observe at least 6 harmonics with none of the harmonics corresponding to an integer hertz frequency value.

The signal was recorded on the digitizer channels for over 30 minutes. In addition, a 5-minute recording was made on the Agilent 3458A reference meter to verify the signal characteristics. This 5-minute limit is due to the signal recording length limits of the meter. The typical measured total harmonic distortion on the reference meter was better than -106 dB. This is lower than the THD measured on each of the digitizer channels. Therefore, it is known that the distortion present in these channels is due to the digitizer and not the generated signal.

A representative set of THD plots are shown below. All of the THD plots were highly similar across the tested digitizers. THD values are provided in the table below for each digitizer channel.

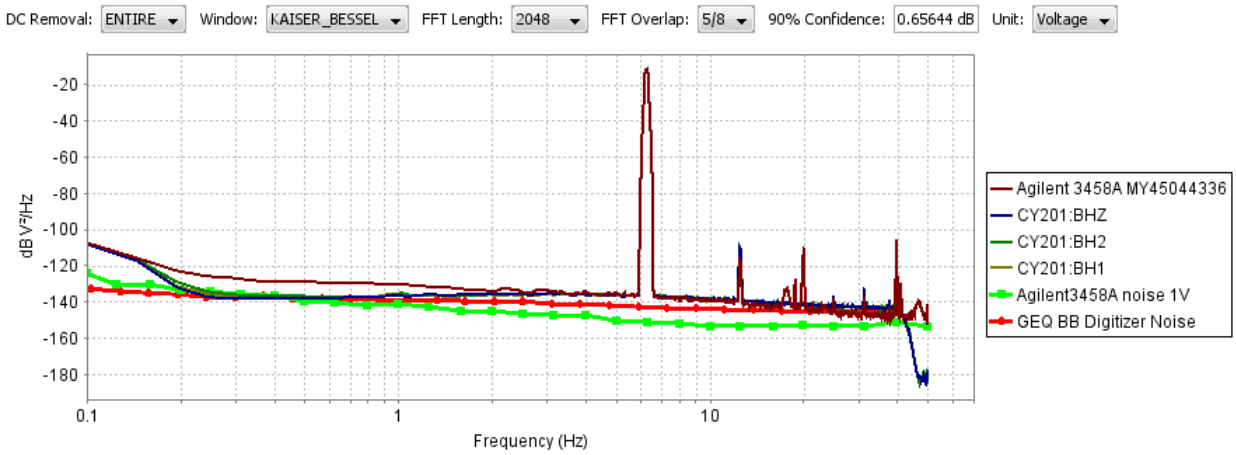


Figure 127 Digitizer BB Total Harmonic Distortion

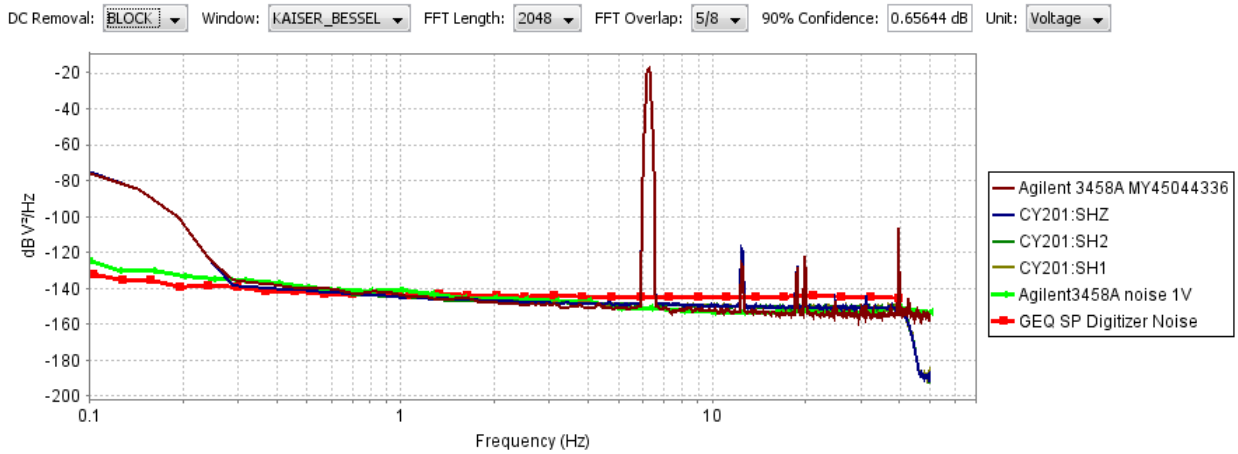


Figure 128 Short-period Total Harmonic Distortion

Table 18 Digitizer Total Harmonic Distortion

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
# 1	-98.99 dB	-97.95 dB	-99.63 dB	-100.42 dB	-99.73 dB	-100.74 dB
# 2	-98.48 dB	-98.53 dB	-98.81 dB	-100.30 dB	-101.68 dB	-101.30 dB
# 3	-99.25 dB	-98.51 dB	-98.27 dB	-99.99 dB	-100.57 dB	-99.99 dB
# 4	-98.42 dB	-99.01 dB	-99.06 dB	-101.24 dB	-101.38 dB	-100.99 dB
# 5	-98.39 dB	-98.75 dB	-98.71 dB	-100.06 dB	-100.92 dB	-101.13 dB
# 6	-98.31 dB	-98.62 dB	-98.47 dB	-100.59 dB	-100.96 dB	-100.79 dB
# 7	-98.96 dB	-98.49 dB	-98.13 dB	-100.64 dB	-101.02 dB	-100.95 dB
# 8	-98.54 dB	-98.86 dB	-98.57 dB	-100.25 dB	-100.54 dB	-100.55 dB
# 9	-98.52 dB	-98.07 dB	-99.02 dB	-101.07 dB	-100.61 dB	-100.61 dB
# 10	-98.94 dB	-99.25 dB	-99.38 dB	-100.50 dB	-101.42 dB	-101.05 dB
# 11	-98.80 dB	-98.99 dB	-98.94 dB	-100.93 dB	-100.30 dB	-101.06 dB
# 12	-99.04 dB	-98.74 dB	-98.94 dB	-101.35 dB	-101.08 dB	-100.73 dB
# 13	-98.72 dB	-99.23 dB	-98.67 dB	-101.71 dB	-100.86 dB	-101.47 dB
# 14	-98.44 dB	-98.75 dB	-98.71 dB	-100.69 dB	-100.27 dB	-99.80 dB
# 15	-98.58 dB	-98.51 dB	-98.50 dB	-100.96 dB	-99.78 dB	-100.03 dB
# 16	-99.02 dB	-98.53 dB	-98.90 dB	-100.84 dB	-100.51 dB	-100.50 dB
# 17	-98.61 dB	-99.28 dB	-98.81 dB	-100.69 dB	-100.56 dB	-100.32 dB
# 18	-99.09 dB	-98.94 dB	-98.09 dB	-101.27 dB	-101.27 dB	-100.41 dB

4.12 Crosstalk

Crosstalk of the digitizer channels was measured by recording a 0.065 V, 10 Hz sinusoid on all of the channels. One at a time, for 3 minutes, each of the channels was terminated with a resistor while the other 5 channels were recording the sinusoid. The nominal resistor value used was 100 ohms for the broadband channels and 100 kohms for the short-period channels. The amount of crosstalk was calculated by computing the ratio of the power at 10 Hz on the terminated channel to the average power present in the sinusoid to the power at 10 Hz present.

Although there was no requirement for crosstalk, it was decided that this would be a valuable metric to measure in order to ensure that there were no issues with the fabrication of the individual units. It is expected that a digitizer with crosstalk of less than -100 dB would be acceptable.

A representative set of crosstalk plots are shown below. All of the crosstalk plots were highly similar across the tested digitizers. Crosstalk values are provided in the table below for each digitizer channel.

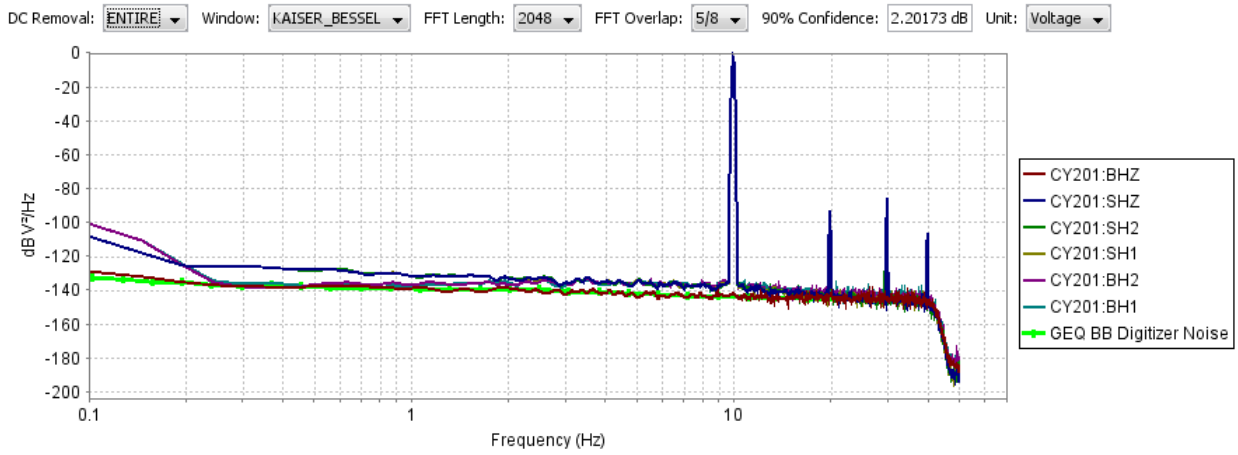


Figure 129 Broadband Vertical Crosstalk

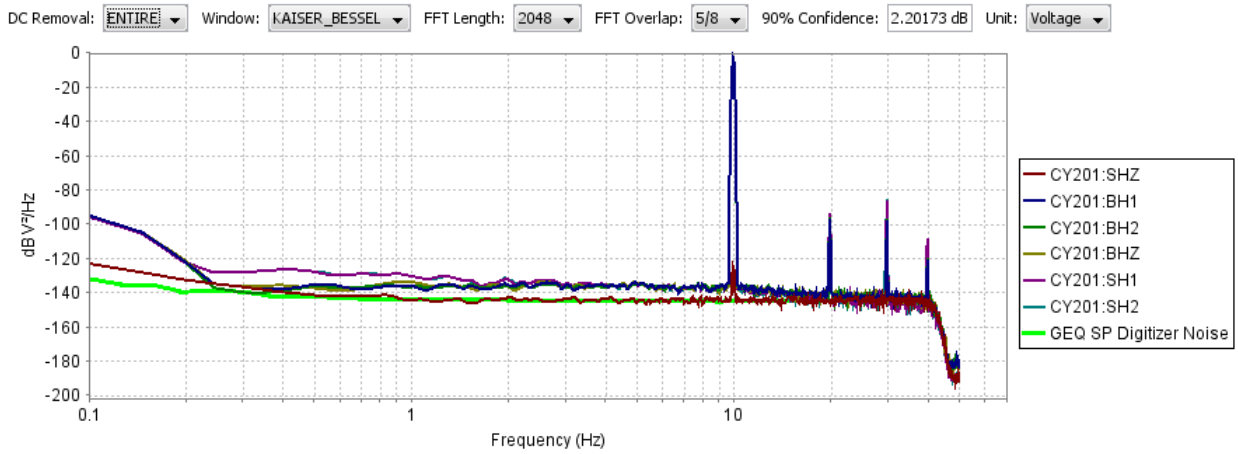


Figure 130 Short-period Vertical Crosstalk

Table 19 Digitizer Crosstalk

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
# 1	-138.42 dB	-134.54 dB	-136.62 dB	-103.42 dB	-111.15 dB	-101.68 dB
# 2	-135.04 dB	-134.98 dB	-134.95 dB	-121.34 dB	-111.62 dB	-111.54 dB
# 3	-138.09 dB	-133.40 dB	-133.51 dB	-122.31 dB	-127.30 dB	-122.95 dB
# 4	-138.27 dB	-131.89 dB	-136.58 dB	-107.08 dB	-115.27 dB	-110.21 dB
# 5	-137.76 dB	-133.94 dB	-133.98 dB	-120.66 dB	-120.70 dB	-111.07 dB
# 6	-138.19 dB	-134.67 dB	-135.95 dB	-106.39 dB	-111.49 dB	-108.38 dB
# 7	-138.03 dB	-134.77 dB	-134.76 dB	-113.04 dB	-119.29 dB	-122.93 dB
# 8	-134.84 dB	-134.93 dB	-137.87 dB	-112.60 dB	-110.89 dB	-108.68 dB
# 9	-138.51 dB	-134.35 dB	-139.17 dB	-111.36 dB	-113.53 dB	-109.09 dB
# 10	-137.80 dB	-134.91 dB	-133.17 dB	-105.60 dB	-114.69 dB	-109.28 dB
# 11	-138.45 dB	-132.82 dB	-136.86 dB	-113.07 dB	-107.87 dB	-106.86 dB
# 12	-137.51 dB	-133.07 dB	-133.18 dB	-108.39 dB	-111.97 dB	-109.86 dB
# 13	-138.31 dB	-133.58 dB	-137.33 dB	-110.96 dB	-112.34 dB	-109.60 dB
# 14	-138.09 dB	-133.11 dB	-137.14 dB	-105.71 dB	-105.30 dB	-104.08 dB
# 15	-137.76 dB	-134.96 dB	-132.83 dB	-121.08 dB	-117.50 dB	-109.42 dB
# 16	-139.02 dB	-133.54 dB	-137.25 dB	-111.22 dB	-110.33 dB	-112.38 dB
# 17	-138.20 dB	-133.61 dB	-134.87 dB	-117.45 dB	-113.81 dB	-110.46 dB
# 18	-134.08 dB	-133.43 dB	-137.08 dB	-115.36 dB	-109.28 dB	-107.23 dB

4.13 Timing Accuracy

The timing accuracy was determined by synchronously recording a 10 Hz sinusoid on all of the SHDAS channels as well as channel 1 on the Smart24. The 10 Hz sinusoid is not time aligned, so the Smart24 channels were first calibrated to determine their individual time bias and the time offset between channels 1 and 2 on the Smart24. A traditional time aligned pulse-per-minute signal was used to calibrate the reference Smart24, averaged over 12 minutes.

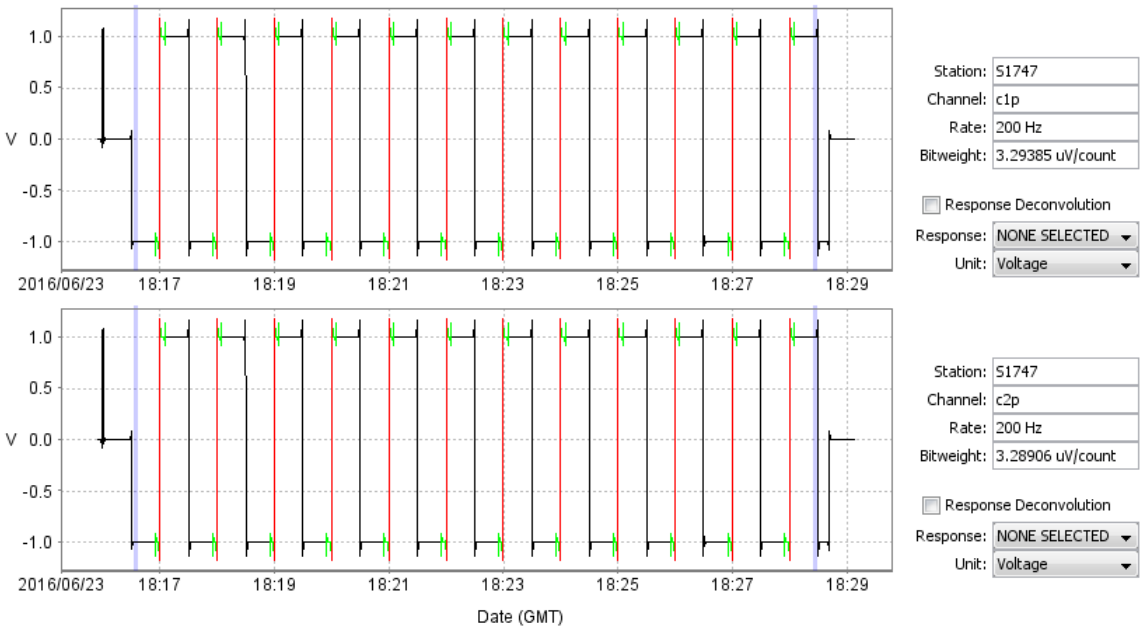


Figure 131 Smart24 PPM Timing Calibration

Table 20 Smart24 PPM Absolute timing error

Channel	Time Error
S1747:c1p	210.10637 us
S1747:c2p	209.19243 us
delta	0.91394 us

There is approximately 210 microseconds of timing bias on the Smart24 channels and the timing skew between the first and second channels is less than 1 microsecond.

Note that in this analysis, timing error is defined to be the difference in time between the measured time stamp and the expected time stamp for a given sample of time series data. As an illustration, two zoomed in views of a PPM recorded on the Smart24 are shown in the figure below. The black line in the figure below connects the actual recorded samples at their assigned time-stamps. The green line represents an interpolated reconstruction filter that does not add frequency content to the signal. The blue vertical line represents when the digitizer has assigned a time-stamp to the second transition. The red vertical line represents the time when the PPM pulse identifies that the actual second transition occurred with the interpolated signal crossing the zero volt threshold.

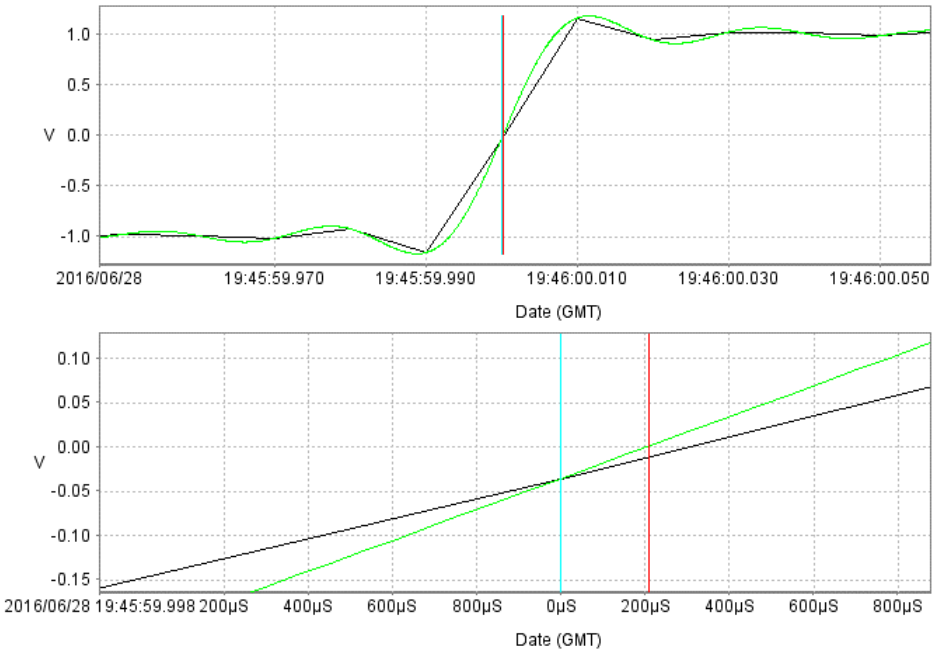


Figure 132 Smart24 PPM Example

As may be seen, at the time when the actual second transition occurred and the expected time stamp is zero microseconds, the digitizer has a measured timestamp of approximately 210 microseconds. Therefore, according to the definition, the timing error is positive 210 microseconds.

We can then proceed to record a non-time-aligned 10 Hz sinusoid on all of the SHDAS channels and channel 1 of the reference Smart24 while simultaneously recording a time-aligned PPM on channel 2 of the Smart24.

The observed difference in the sinusoids phase will then be measured between the SHDAS channels and channel 1 of the Smart24. This phase offset can then be converted to a time offset at 10 Hz to identify the relative timing bias between the SHDAS channels and Smart24 channel 1. The PPM on Smart24 channel 2 will provide the absolute correction to the observed sinusoid on channel 1 with less than 1 microsecond of error.

The timing signal is run for between 10 and 15 minutes on each digitizer and the results are calculated at each minute transition. The timing errors are averaged over the duration of the test. The standard deviations of the measured timing errors have been less than 0.2 microseconds, indicating that the results are repeatable for the duration of the timing test.

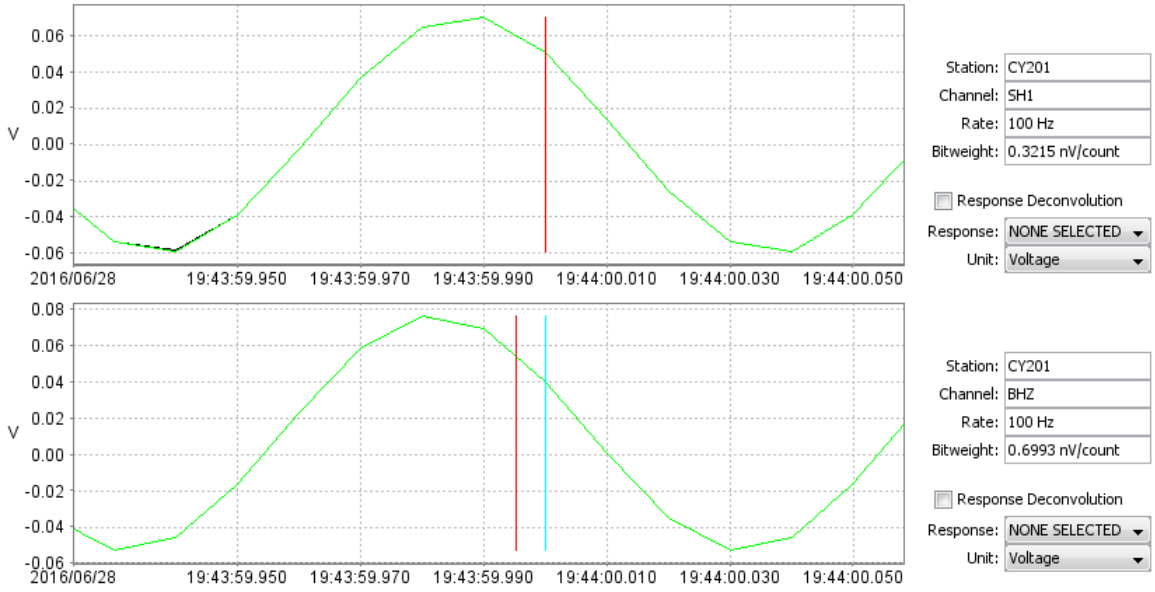


Figure 133 SHDAS digitizer 10 Hz Relative Timing

Table 21 SHDAS digitizer 10 Hz Relative Timing, without preamp correction

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
# 1	4,852 us	4,933 us	4,895 us	-81 us	-91 us	-85 us
# 2	4,752 us	4,772 us	4,764 us	-91 us	-80 us	-88 us
# 3	4,791 us	4,765 us	4,777 us	-81 us	-82 us	-91 us
# 4	4,827 us	4,922 us	4,859 us	-81 us	-77 us	-91 us
# 5	4,906 us	4,852 us	4,883 us	-93 us	-75 us	-89 us
# 6	4,869 us	4,837 us	4,911 us	-90 us	-74 us	-92 us
# 7	4,618 us	4,651 us	4,603 us	-326 us	-328 us	-330 us
# 8	4,852 us	4,857 us	4,902 us	-94 us	-77 us	-84 us
# 9	4,853 us	4,914 us	4,798 us	-86 us	-88 us	-87 us
# 10	4,915 us	4,856 us	4,913 us	-86 us	-89 us	-85 us
# 11	4,948 us	4,868 us	4,889 us	-86 us	-76 us	-87 us
# 12	4,811 us	4,841 us	4,894 us	-112 us	-113 us	-115 us
# 13	4,907 us	4,846 us	4,914 us	-82 us	-95 us	-81 us
# 14	4,875 us	4,821 us	4,818 us	-123 us	-126 us	-120 us
# 15	4,840 us	4,793 us	4,817 us	-121 us	-118 us	-115 us
# 16	3,716 us	3,716 us	3,723 us	-1,186 us	-1,174 us	-1,185 us
# 17	4,610 us	4,614 us	4,628 us	-258 us	-261 us	-252 us
# 18	4,852 us	4,873 us	4,823 us	-116 us	-124 us	-123 us

At 10 Hz, the nominal response for the broadband preamplifier has a phase delay of 17.7445 degrees which corresponds to 4937.3 microseconds. Correcting the relative timing offsets for the nominal preamplifier response results in the values below:

Table 22 SHDAS digitizer 10 Hz Relative Timing, with nominal preamp correction

Digitizer	BHZ	BH2	BH1	SHZ	SH2	SH1
# 1	-86 us	-4 us	-42 us	-81 us	-91 us	-85 us
# 2	-186 us	-165 us	-173 us	-91 us	-80 us	-88 us
# 3	-146 us	-173 us	-160 us	-81 us	-82 us	-91 us
# 4	-110 us	-16 us	-79 us	-81 us	-77 us	-91 us
# 5	-31 us	-85 us	-55 us	-93 us	-75 us	-89 us
# 6	-68 us	-100 us	-26 us	-90 us	-74 us	-92 us
# 7	-320 us	-287 us	-335 us	-326 us	-328 us	-330 us
# 8	-86 us	-80 us	-35 us	-94 us	-77 us	-84 us
# 9	-84 us	-23 us	-139 us	-86 us	-88 us	-87 us
# 10	-22 us	-81 us	-24 us	-86 us	-89 us	-85 us
# 11	11 us	-69 us	-49 us	-86 us	-76 us	-87 us
# 12	-127 us	-96 us	-43 us	-112 us	-113 us	-115 us
# 13	-31 us	-92 us	-23 us	-82 us	-95 us	-81 us
# 14	-63 us	-116 us	-119 us	-123 us	-126 us	-120 us
# 15	-97 us	-144 us	-121 us	-121 us	-118 us	-115 us
# 16	-1,222 us	-1,221 us	-1,214 us	-1,186 us	-1,174 us	-1,185 us
# 17	-328 us	-323 us	-309 us	-258 us	-261 us	-252 us
# 18	-85 us	-64 us	-114 us	-116 us	-124 us	-123 us

Correcting for the measured offset of the PPM recorded on channel 2 of the Smart24 digitizer results in the following timing numbers.

Table 23 SHDAS digitizer 10 Hz Absolute Timing

Digitizer	Smart24 Ch2 PPM Offset	BHZ	BH2	BH1	SHZ	SH2	SH1
# 1	211 us	-297 us	-215 us	-253 us	-293 us	-302 us	-296 us
# 2	209 us	-395 us	-375 us	-383 us	-300 us	-289 us	-298 us
# 3	211 us	-357 us	-383 us	-371 us	-292 us	-293 us	-301 us
# 4	211 us	-321 us	-226 us	-289 us	-292 us	-288 us	-302 us
# 5	211 us	-242 us	-296 us	-266 us	-304 us	-286 us	-300 us
# 6	211 us	-279 us	-311 us	-237 us	-301 us	-285 us	-303 us
# 7	211 us	-531 us	-498 us	-546 us	-537 us	-539 us	-541 us
# 8	211 us	-297 us	-291 us	-246 us	-305 us	-288 us	-295 us
# 9	211 us	-295 us	-234 us	-350 us	-297 us	-299 us	-298 us
# 10	212 us	-234 us	-293 us	-236 us	-298 us	-301 us	-297 us
# 11	212 us	-201 us	-281 us	-260 us	-297 us	-288 us	-299 us
# 12	211 us	-338 us	-307 us	-254 us	-323 us	-324 us	-326 us
# 13	211 us	-242 us	-303 us	-234 us	-293 us	-306 us	-292 us
# 14	210 us	-273 us	-327 us	-329 us	-334 us	-337 us	-330 us
# 15	210 us	-308 us	-355 us	-331 us	-332 us	-328 us	-326 us
# 16	211 us	-1,433 us	-1,433 us	-1,426 us	-1,397 us	-1,385 us	-1,396 us
# 17	211 us	-539 us	-534 us	-520 us	-469 us	-472 us	-464 us
# 18	211 us	-296 us	-275 us	-325 us	-327 us	-335 us	-334 us

Note: Timing results are preliminary as they were all evaluated using a prototype SNIB and either a prototype or single-production SNIT. It is expected that these results may change with the final timing evaluation against the production SNIBs and SNITs and with the addition of inter-node (5 km) and truck (200 km) fiber-optic cables.

Also, it was later determined that during the testing of #7, #16, and #17 the prototype SNIB and SNIT were experiencing timing issues that resulted in measurable drift. Further testing of timing accuracy will be performed during system integration.

4.14 Timing Accuracy – System Integration

The timing accuracy tests were repeated during system integration when the ePV's were paired with their mission SNIBs and SNITs at Pt. Hueneme. At this point, the ePV's were assembled into their mission configuration including the use of internode cabling between the elements of the arrays. The table below shows which ePV was assigned to each channel code and the associated length of fiber cabling between them.

Figure 134 System Integration Testing

Table 24 SHDAS Channel Code and ePV Configuration

Station Code	ePV #	Smart24 S1811 & S1579 Channel	Fiber length to next component (m)	Cumulative Fiber length to SNIB (m)
CY101	2	1	2994	2994
CY201	4	1	3016	3016
CY301	7	1	2991	2991
CY302	12	2	5588	8579
CY303	14	3	2068	10647
CY304	15	4	3610	14257
CY305	16	5	3481	17738
CY306	18	6	3637	21375
CY401	6	1	2996	2996
CY501	3	1	2997	2997
CY601	1	1	2995	2995
CY602	13	2	5588	8583
CY603	17	3	2068	10651
CY604	9	4	3612	14263
CY605	5	5	3481	17744
CY606	8	6	3637	21381

Two Geotech Smart24's connected to the ePV's sensor inputs were used as a signal source for timing measurement. The two Smart24's were slaved together using a single GPS antenna so that they were recording synchronously. The testing may be performed on a single ePV element at a time or on as many as 6 elements simultaneously.

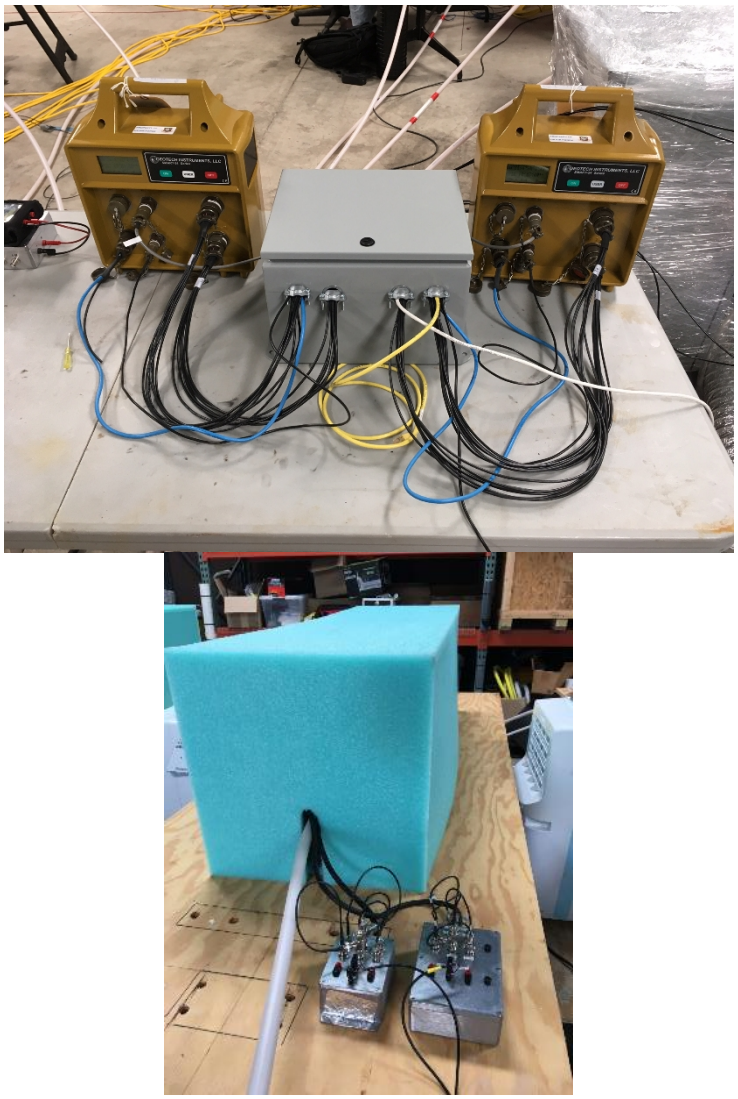


Figure 135 System Integration Timing Testbed

Each Smart24 has 6 calibrator output lines and has the ability to generate an identical signal simultaneously on all 6 lines. Each calibrator output line is electrically isolated with an individual buffering amplifier from the remaining lines. If multiple ePV's are tested at once, a single calibrator output will be dedicated to each ePV.

One of the Smart24's will be configured to generate the signals for the Trillium Broad-band channels and the other Smart24 will be configured to generate the signals for the Navy OBS Short-period channels. Each calibration output channel is externally looped back to its respective Smart24 digital recording channel.

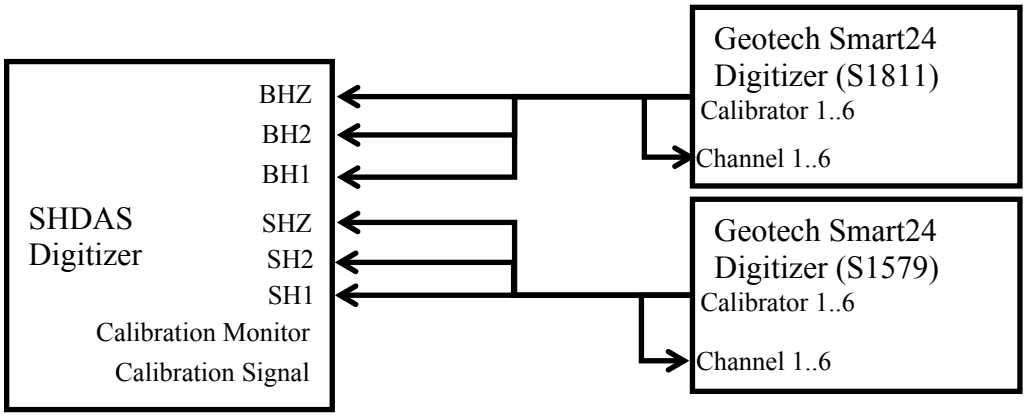


Figure 136 System Timing Configuration Diagram

One complication with this approach is that each reference recording channel on the Smart24s may have a slightly different time delay and, although specified to be identical, each calibrator output on the Smart24s may have a slightly different delay through its amplifier. In order to address this, the channel 1 and calibrator 1 on the S1579 are treated as the reference. The output of calibrator 1 is assumed to have no timing offset in its signal. The timing offset of channel 1 may be directly measured and all timing measurements are corrected back to be normalized to channel 1.

To address this uncertainty in the time offsets in the remaining channels, a set of baseline tests was performed to better compare the differences in the Smart24's. In the first baseline test, the calibrator output from channel one on Smart24 S1579 was configured to generate 15 minutes of first a 10 Hz sinusoid and then a PPM signal. The generated signal was fed simultaneously into all of the recording channels on both Smart24s.

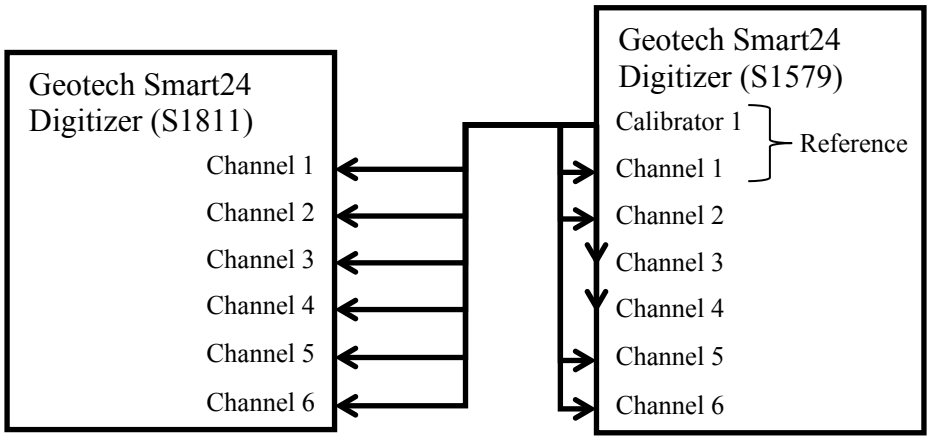


Figure 137 Digitizer Timing Baseline Common Signal

The observed time offsets from these tests are assumed to be the sum of the time offset in the recording channel and the time offset in the calibrator output for both the reference channel and all remaining channels:

$$t_{obs_{ref}} = t_{S24_{chan\ ref}} + t_{S24_{cal\ ref}}$$
$$t_{obs_{S24\ i}} = t_{S24_{chan\ i}} + t_{S24_{cal\ ref}}$$

The relative difference between the observed timing offsets is entirely due to the differences in the recording channel since they share a common calibration signal

$$t_{obs_{S24\ i}} - t_{obs_{ref}} = t_{S24_{chan\ i}} - t_{S24_{chan\ ref}}$$

Table 25 Digitizer Timing Baseline Common Signal

Digitizer Channel	PPM Absolute	PPM Relative to S1579 / Channel 1	10 Hz Sine Relative to S1579 / Channel 1
S1579 / Channel 1	268.6 us		
S1579 / Channel 2	269.7 us	1.1 us	1.0 us
S1579 / Channel 3	269.3 us	0.8 us	0.6 us
S1579 / Channel 4	270.6 us	2.0 us	1.8 us
S1579 / Channel 5	269.1 us	0.5 us	0.4 us
S1579 / Channel 6	269.5 us	0.9 us	0.9 us
S1811 / Channel 1	269.1 us	0.5 us	0.7 us
S1811 / Channel 2	270.8 us	2.2 us	2.4 us
S1811 / Channel 3	268.7 us	0.1 us	0.1 us
S1811 / Channel 4	269.8 us	1.2 us	1.2 us
S1811 / Channel 5	269.9 us	1.3 us	1.2 us
S1811 / Channel 6	269.4 us	0.8 us	0.9 us

The results in the table above indicate that all of the digitizer channels are able to time-stamp data with consistency that is within 2.4 micro-seconds of one another. Also, since the time delay of the S1579 Calibrator 1 is assumed to be zero, the PPM Absolute column in the above table may be used to represent each recording channels timing offset.

In the second baseline test, each calibrator output is externally looped back to just its respective recording channel. The calibrator outputs were then configured to generate 15 minutes of first a 10 Hz sinusoid and then a PPM signal.

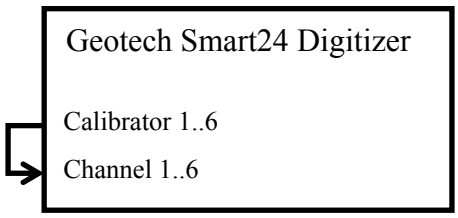


Figure 138 Digitizer Timing Baseline Unique Signals

In this case, the observed time offsets are now based upon the inferred time delay in each of the calibrator outputs:

$$t_{obs_{ref}} = t_{S24_{chan\,ref}} + t_{S24_{cal\,ref}}$$
$$t_{obs_{S24\,i}} = t_{S24_{chan\,i}} + t_{S24_{cal\,i}}$$

Based upon the earlier result in which the recording channel timing delay was determined to be effectively equal for all channels, the relative difference between the observed timing offsets may be assumed to be dominated by the calibration signal time offset:

$$t_{obs_{S24\,i}} - t_{obs_{ref}} = t_{S24_{cal\,i}} - t_{S24_{cal\,ref}}$$

The result of this second baseline test is to determine the timing offset due to the recording channel plus the delay of the individual calibrator signals. Any difference between the results in the first and second baseline tests represents the contribution of the calibrator amplifier delay.

Table 26 Digitizer Timing Baseline Unique Signals

Digitizer Channel	PPM Absolute	PPM Relative to S1579 / Channel 1	10 Hz Sine Relative to S1579 / Channel 1
S1579 / Channel 1	281.2 us		
S1579 / Channel 2	282.4 us	1.2 us	1.1 us
S1579 / Channel 3	281.8 us	0.6 us	0.6 us
S1579 / Channel 4	282.8 us	1.6 us	1.8 us
S1579 / Channel 5	281.8 us	0.6 us	0.5 us
S1579 / Channel 6	292.5 us	11.3 us	8.6 us
S1811 / Channel 1	327.3 us	46.1 us	-2.2 us
S1811 / Channel 2	328.9 us	47.7 us	-0.5 us
S1811 / Channel 3	326.4 us	45.2 us	-2.7 us
S1811 / Channel 4	327.6 us	46.4 us	-1.7 us
S1811 / Channel 5	327.7 us	46.5 us	-1.7 us
S1811 / Channel 6	327.4 us	46.2 us	-2.0 us

We observe that the amplifier for the S1579 calibrator #6 output introduces approximately 10 microseconds of additional signal delay. In addition, the PPM generated by the S1811 calibrator outputs has approximately 45 microseconds of additional delay. These delays are known to be due to the signal from the calibrator output because the channel time-stamping shown in Table 25 are consistent between the channels. Based upon these results, there do appear to be differences in the time delay due to the respective calibrator outputs. Therefore, evaluation of the SHDAS timing delays will be made as a relative measure between the SHDAS timing delay and the Smart24 loopback timing delay so that the impact of the calibrator will cancel out.

The timing accuracy test was performed individually on each of the single stations. For each of the arrays, the timing accuracy test was performed on all 6 elements of the array simultaneously. The figure below represents the configuration of the equipment used at the time of the test. The ePV's configured as spares were not evaluated during system integration.

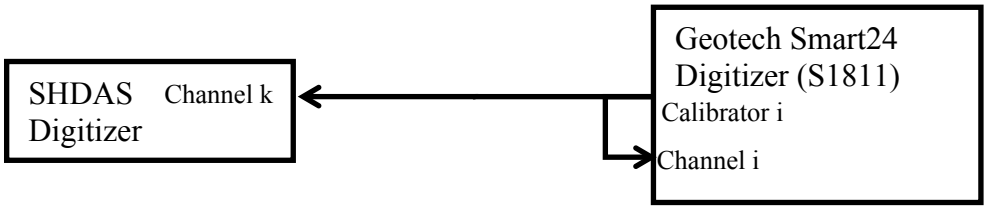


Figure 139 SHDAS Digitizer Time Offset Model

The observed time offsets are measured on each SHDAS channel and the respective looped back Smart24 channel:

$$t_{obs_{S24\,i}} = t_{S24_{chan\,i}} + t_{S24_{cal\,i}}$$

$$t_{obs_{SHDAS\,k}} = t_{SHDAS_{chan\,k}} + t_{S24_{cal\,i}}$$

Taking the relative observed time offset between the SHDAS channel and the Smart24 looped back channel yields:

$$t_{obs_{SHDAS\,k}} - t_{obs_{S24\,i}} = t_{SHDAS_{chan\,k}} - t_{S24_{chan\,i}}$$

The time offset of the SHDAS channel may then be solved for by correcting for the time offset of the Smart24 channel, from the PPM Absolute column in Table 25, to the relative observed time offset:

$$t_{SHDAS_{chan\,k}} = t_{obs_{SHDAS\,k}} - t_{obs_{S24\,i}} + t_{S24_{chan\,i}}$$

For each iteration of the timing accuracy test, there were three phases of testing performed:

1. 15 minutes of 0.065 Vpeak, 10 Hz sinusoid on both S1811 and S1579.
2. 15 minutes of 0.065 Vpeak, 10 Hz sinusoid on S1811 and 0.065 Vpeak, PPM on S1579.
3. 15 minutes of 0.065 Vpeak PPM on both S1811 and S1579.

In the first phase of timing accuracy, a 10 Hz sinusoid is introduced on all channels simultaneously for a consistent measurement signal that may be used to compare both the Broadband and Short-period channels. This method obtains a measure of timing relative to the Smart24 time stamp. In the table below, the observed relative time delays and the values corrected with the Smart24 offsets from Table 25 were added to the 10 Hz relative timing offset.

Table 27 System Time Offset, 10 Hz Sine on Broadband and Short-period

Station Code	ePV #	BHZ Relative	Corrected	BH2 Relative	Corrected	BH1 Relative	Corrected	SHZ Relative	Corrected	SH2 Relative	Corrected	SH1 Relative	Corrected
101	2	-4775 us	-4506 us	-4795 us	-4526 us	-4786 us	-4517 us	69 us	338 us	58 us	327 us	67 us	335 us
201	4	-4853 us	-4584 us	-4947 us	-4677 us	-4884 us	-4615 us	60 us	328 us	56 us	324 us	69 us	338 us
301	7	-4881 us	-4612 us	-4915 us	-4645 us	-4866 us	-4597 us	65 us	333 us	67 us	336 us	69 us	337 us
302	12	-4892 us	-4621 us	-4923 us	-4653 us	-4975 us	-4704 us	36 us	305 us	36 us	306 us	39 us	309 us
303	14	-4914 us	-4645 us	-4917 us	-4648 us	-4971 us	-4703 us	27 us	297 us	30 us	300 us	24 us	293 us
304	15	-4955 us	-4685 us	-4908 us	-4638 us	-4931 us	-4662 us	-6 us	264 us	-3 us	268 us	0 us	271 us
305	16	-4908 us	-4638 us	-4908 us	-4638 us	-4915 us	-4645 us	-5 us	264 us	-17 us	252 us	-6 us	263 us
306	18	-4973 us	-4704 us	-5034 us	-4765 us	-4968 us	-4698 us	-5 us	265 us	2 us	271 us	1 us	270 us
401	6	-4894 us	-4625 us	-4861 us	-4592 us	-4935 us	-4666 us	68 us	337 us	52 us	321 us	70 us	339 us
501	3	-4813 us	-4544 us	-4785 us	-4516 us	-4798 us	-4529 us	61 us	329 us	62 us	330 us	70 us	339 us
601	1	-4875 us	-4606 us	-4956 us	-4687 us	-4919 us	-4650 us	60 us	329 us	69 us	338 us	63 us	332 us
602	13	-4959 us	-4689 us	-4898 us	-4627 us	-4967 us	-4696 us	32 us	302 us	45 us	315 us	32 us	301 us
603	17	-4838 us	-4569 us	-4842 us	-4574 us	-4857 us	-4588 us	29 us	299 us	32 us	301 us	24 us	293 us
604	9	-4933 us	-4663 us	-4993 us	-4723 us	-4877 us	-4608 us	8 us	278 us	9 us	280 us	8 us	279 us
605	5	-5003 us	-4733 us	-4948 us	-4678 us	-4978 us	-4708 us	-6 us	263 us	-19 us	250 us	-1 us	268 us
606	8	-4969 us	-4700 us	-4969 us	-4699 us	-4994 us	-4725 us	1 us	270 us	-15 us	255 us	-9 us	261 us

The second phase of timing accuracy introduces a PPM on the short-period channels in order to validate the absolute timing of both the short-period channels and on the Smart24 S1579 recording channels.

Table 28 System Time Offset, 10 Hz Sine on Broadband and PPM on Short-period

Station Code	ePV #	BHZ Relative	Corrected	BH2 Relative	Corrected	BH1 Relative	Corrected	SHZ Relative	Corrected	SH2 Relative	Corrected	SH1 Relative	Corrected
101	2	-4775 us	-4506 us	-4795 us	-4526 us	-4787 us	-4517 us	68 us	336 us	57 us	325 us	65 us	334 us
201	4	-4852 us	-4583 us	-4946 us	-4677 us	-4883 us	-4614 us	58 us	327 us	54 us	323 us	68 us	337 us
301	7	-4881 us	-4612 us	-4914 us	-4645 us	-4866 us	-4597 us	68 us	337 us	67 us	335 us	64 us	333 us
302	12	-4892 us	-4621 us	-4924 us	-4653 us	-4975 us	-4704 us	34 us	304 us	35 us	305 us	38 us	307 us
303	14	-4971 us	-4702 us	-4917 us	-4648 us	-4914 us	-4646 us	26 us	295 us	29 us	298 us	23 us	292 us
304	15	-4955 us	-4685 us	-4908 us	-4638 us	-4931 us	-4661 us	5 us	275 us	1 us	272 us	-1 us	269 us
305	16	-4908 us	-4638 us	-4908 us	-4638 us	-4915 us	-4645 us	-6 us	263 us	-18 us	251 us	-7 us	262 us
306	18	-4993 us	-4724 us	-5014 us	-4744 us	-4964 us	-4694 us	-9 us	260 us	-3 us	267 us	-4 us	266 us
401	6	-4893 us	-4624 us	-4860 us	-4591 us	-4935 us	-4666 us	67 us	335 us	50 us	319 us	69 us	337 us
501	3	-4812 us	-4543 us	-4785 us	-4516 us	-4798 us	-4529 us	59 us	328 us	60 us	329 us	69 us	337 us
601	1	-4875 us	-4606 us	-4957 us	-4688 us	-4919 us	-4650 us	59 us	327 us	68 us	336 us	62 us	330 us
602	13	-4959 us	-4677 us	-4898 us	-4616 us	-4967 us	-4685 us	31 us	301 us	44 us	314 us	31 us	300 us
603	17	-4838 us	-4554 us	-4842 us	-4558 us	-4857 us	-4573 us	29 us	298 us	31 us	300 us	23 us	292 us
604	9	-4932 us	-4649 us	-4993 us	-4710 us	-4877 us	-4594 us	6 us	277 us	8 us	279 us	7 us	278 us
605	5	-5002 us	-4719 us	-4948 us	-4665 us	-4978 us	-4696 us	-7 us	262 us	-20 us	249 us	-3 us	267 us
606	8	-4964 us	-4681 us	-4971 us	-4688 us	-5015 us	-4732 us	-4 us	266 us	-19 us	250 us	-14 us	256 us

The third phase of timing accuracy introduces a PPM on the broad-band channels, which cannot be observed due to the preamplifier filter, but validates the absolute timing of the Smart24 S1811 recording channels.

Table 29 System Time Offset, PPM on Broadband and Short-period

Station Code	ePV #	SHZ Relative	Corrected	SH2 Relative	Corrected	SH1 Relative	Corrected
101	2	68 us	336 us	57 us	325 us	65 us	334 us
201	4	58 us	327 us	54 us	323 us	68 us	337 us
301	7	64 us	333 us	67 us	335 us	68 us	337 us
302	12	38 us	307 us	35 us	305 us	35 us	304 us
303	14	26 us	295 us	29 us	298 us	23 us	292 us
304	15	5 us	275 us	1 us	272 us	-1 us	269 us
305	16	-7 us	262 us	-19 us	251 us	-8 us	261 us
306	18	-10 us	260 us	-3 us	266 us	-4 us	266 us
401	6	67 us	336 us	51 us	319 us	69 us	338 us
501	3	69 us	337 us	61 us	329 us	60 us	328 us
601	1	62 us	330 us	68 us	336 us	59 us	327 us
602	13	31 us	301 us	44 us	314 us	31 us	300 us
603	17	29 us	298 us	31 us	301 us	23 us	292 us
604	9	7 us	277 us	8 us	279 us	8 us	278 us
605	5	-2 us	267 us	-20 us	249 us	-7 us	263 us
606	8	-4 us	266 us	-19 us	250 us	-13 us	256 us

Evaluating the corrected timing offsets in Table 27, Table 28, and Table 29 reveals that all three tests yielded very consistent results and that there appears to be a relationship between the timing offset and the amount of cable between the ePV and the SNIB. The figures below plot the time offsets for each of the measurements made versus the fiber cable length.

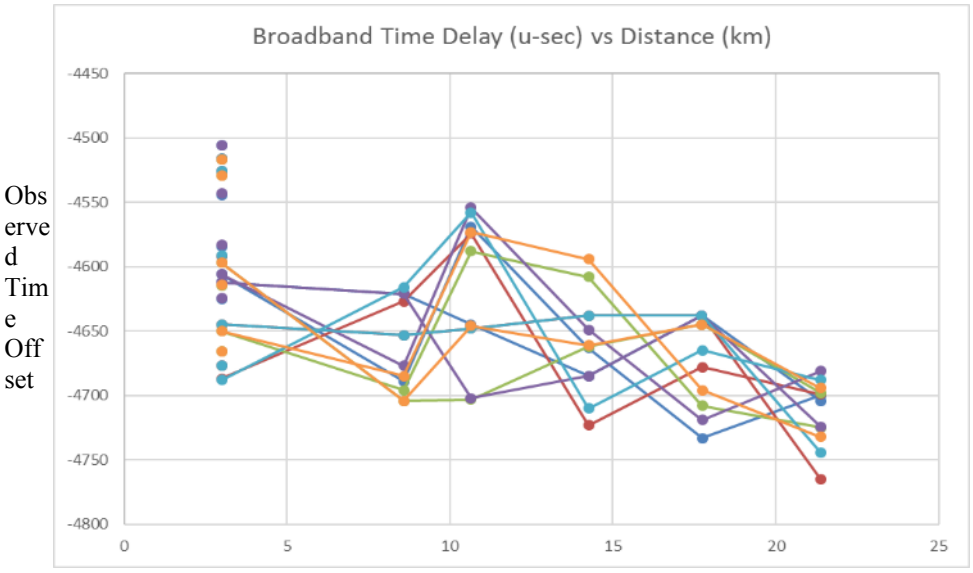


Figure 140 Broadband Time Offset vs Cable Length

There appears to be a slight trend on the broadband channels versus distance. However, the variability from one channel to the next is more significant than the overall trend versus distance. This is likely due to differences in the broadband preamplifier filters delay.

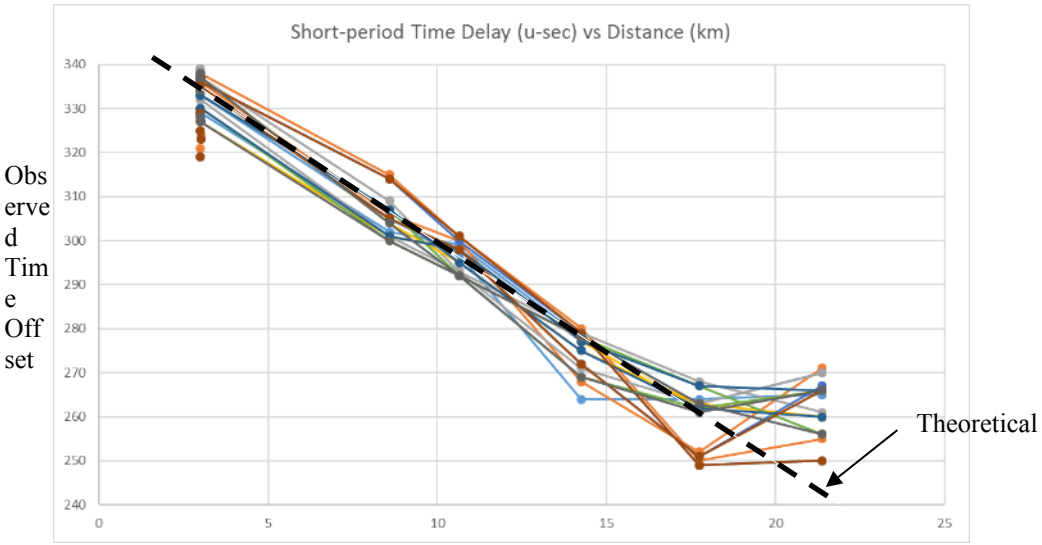


Figure 141 Short-period Time Offset vs Cable Length

On the short-period channels, which does not contain a filter within the preamplifier, the trend of time offset versus distance is much more visible. It appears that the approximate relationship between the time offset in microseconds and cable length in meters is:

$$t_{us} = 350 - 10^6 * \frac{d}{\frac{2}{3} * c}, where$$

d *is the cable distance in meters and*
c *is the speed of light in a vacuum* $(3 * 10^8\ m/s)$

The recording channel time offset is approximately 350 microseconds minus the propagation time through the length of fiber optic cable in which it is assumed that the propagation speed in fiber is 2/3 of the propagation speed of light in a vacuum.

In addition, the SHDAS has the capability to adjust the timing signal being sent to each of the ePVs. Several tests were performed in which the shore-station was configured with different adjustments to the timing signal for each station. The results of these tests are shown in the table below.

Table 30 SHDAS Timing Adjustment

Station Code	ePV #	Fiber Cable Length (km)	SHDAS Time Adjustment	Expected	SHZ	SH2	SH1
601	1	2.995	300 us	35 us	36 us	45 us	39 us
601	1	2.995	-700 us	1035 us	1031 us	1037 us	1028 us
601	1	2.995	344 us	-9 us	-15 us	-6 us	-12 us
602	13	8.583	320 us	-13 us	-18 us	-5 us	-19 us
603	17	10.651	310 us	-13 us	-11 us	-8 us	-17 us
604	9	14.263	290 us	-11 us	-12 us	-10 us	-11 us
605	5	17.744	275 us	-14 us	-7 us	-25 us	-12 us
606	8	21.381	270 us	-27 us	-19 us	-36 us	-29 us

The SHDAS shore-system was able to be configured with timing offsets that would adjust the observed timing delay. These tests demonstrated that the timing adjustment capability can effectively eliminate the approximate timing delay of the recording channel and account for any propagation delay due to the length of the fiber optic cable. The observed timing offsets on channels SHZ, SH2, and SH1 matched almost exactly the expected timing offset based upon the ePV timing bias of 350 microseconds, the known fiber cable lengths, and the programmed shore-station time adjustments.

4.15 Calibrator – Sensitivity

The sensitivity of the calibrator may be determined by commanding the SHDAS to run a calibration using a 10 Hz sinusoid with an amplitude of 12 dB for 100 seconds, the maximum duration allowed by the SHDAS. Relays on the SHDAS digitizer route the calibration signal simultaneously to both a calibration monitor channel and to an external calibration line on the broadband channels. Utilizing this external calibration line, we are able to make a recording of this calibration signal on the reference meter in order to make a traceable estimate of the monitor channel bit-weight.

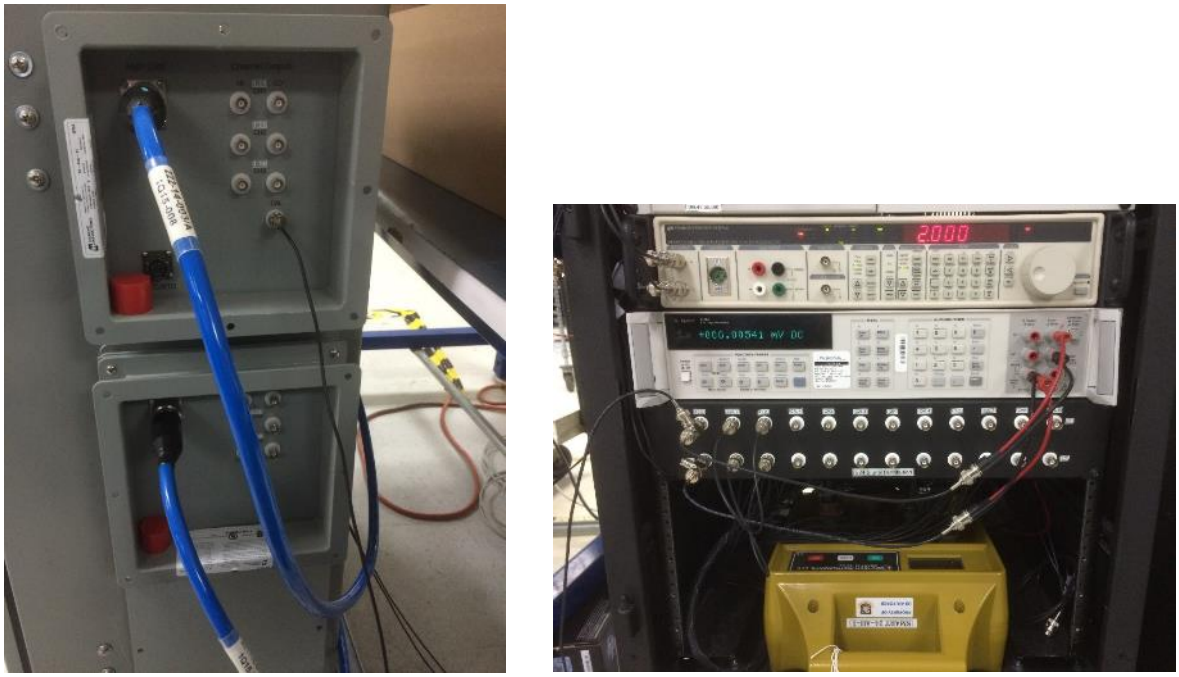


Figure 142 Production Test Station Calibration Line

Note that in this phase of the SHDAS calibration, a single-ended calibration signal is routed to both the calibration monitor channel and the external calibration line. There is no need to compensate for measurement of a differential vs signal-ended measurement.

Measurements were made on the first production unit of the monitor channel bitweight at all of the output amplitude levels: 0 dB, 6 dB, 12 dB, and 18 dB. The results were identical in all cases and so in subsequent production units the test was only run at 12 dB. The 12 dB selection corresponds to a peak-to-peak amplitude of approximately 0.9 V.

The sinusoid amplitudes were determined by applying a least-squared sine fit to 50 seconds (500 cycles) of data from the recordings on both the SHDAS digitizer and the reference meter. No other filtering or processing of the data was performed.

The sensitivities were then calculated by computing the ratio between the reference meter amplitude in volts divided by the digitizer channel amplitude in counts.

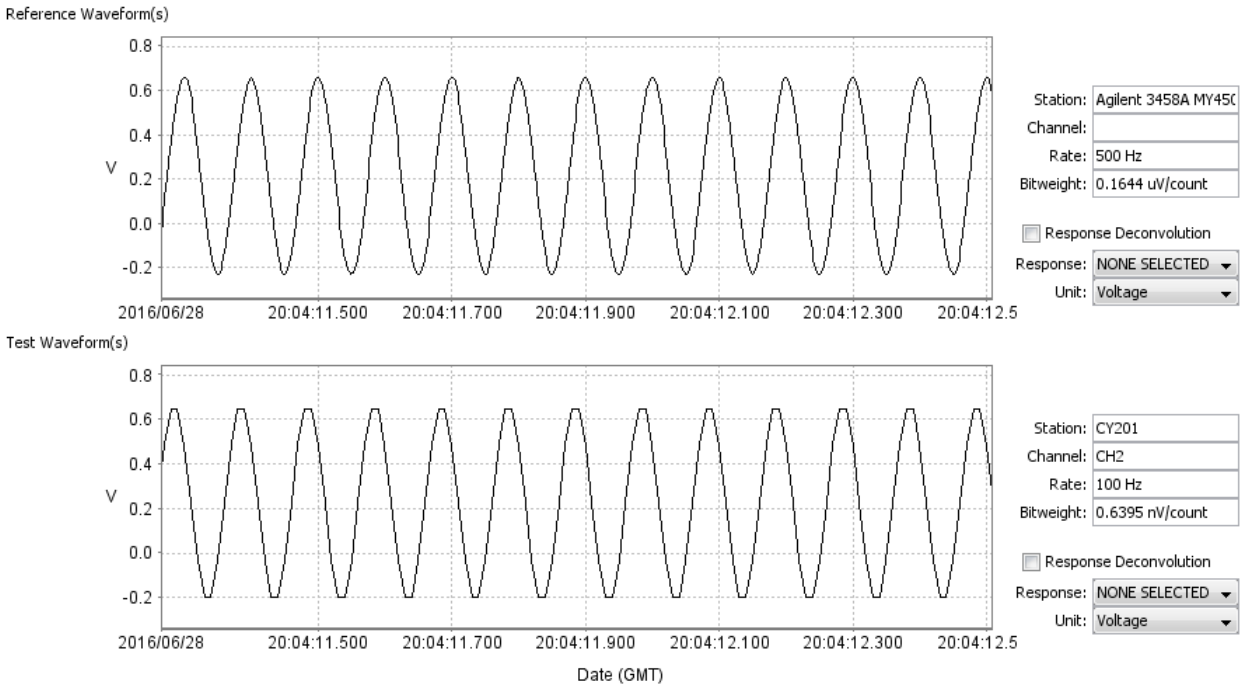


Figure 143 Calibration Monitor Channel 10 Hz Sensitivity

Note that the calibration monitor channel in the figure above, CH2, is not observing clipping on the peaks of the sinusoid. There is limited time resolution of the 10 Hz sinusoid when sampled at 100 Hz and the time samples simply happen to not coincide with the peaks of the sinusoid.

Table 31 SHDAS digitizer Calibrator Monitor Channel Sensitivity

Digitizer	CH2
# 1	0.6383 nV/count
# 2	0.6393 nV/count
# 3	0.6386 nV/count
# 4	0.6399 nV/count
# 5	0.6385 nV/count
# 6	0.6403 nV/count
# 7	0.6408 nV/count
# 8	0.6380 nV/count
# 9	0.6374 nV/count
# 10	0.6390 nV/count
# 11	0.6391 nV/count
# 12	0.6411 nV/count
# 13	0.6402 nV/count
# 14	0.6395 nV/count
# 15	0.6398 nV/count
# 16	0.6404 nV/count
# 17	0.6395 nV/count
# 18	0.6375 nV/count

4.16 Calibrator – Linearity

The linearity of the calibration signal and the calibration monitor channel may be determined by commanding the SHDAS to run a calibration using a 6.28 Hz sinusoid with an amplitude of 12 dB for 100 seconds, the maximum duration allowed by the SHDAS. More than 2 minutes of data ends up being generated. The entire length of the sinusoid was analyzed to determine its total harmonic distortion.

Relays on the SHDAS digitizer route the calibration signal simultaneously to both an internal calibration monitor channel and to an external calibration line on the broadband channels. Utilizing this external calibration line, we are able to make a recording of this calibration signal on the Agilent 3458A reference meter in order to make a traceable estimate of the calibration signal characteristics and the calibration monitor channel.

Note that in this phase of the SHDAS calibration, a single-ended calibration signal is routed to both the calibration monitor channel and the external calibration line. There is no need to compensate for measurement of a differential vs signal-ended measurement.

Measurements were made on the first production unit of the calibrator linearity at all of the output amplitude levels: 0 dB, 6 dB, 12 dB, and 18 dB. The results were identical in all cases and so in subsequent production units the test was only run at 12 dB. The 12 dB selection corresponds to a peak-to-peak amplitude of approximately 0.9 V.

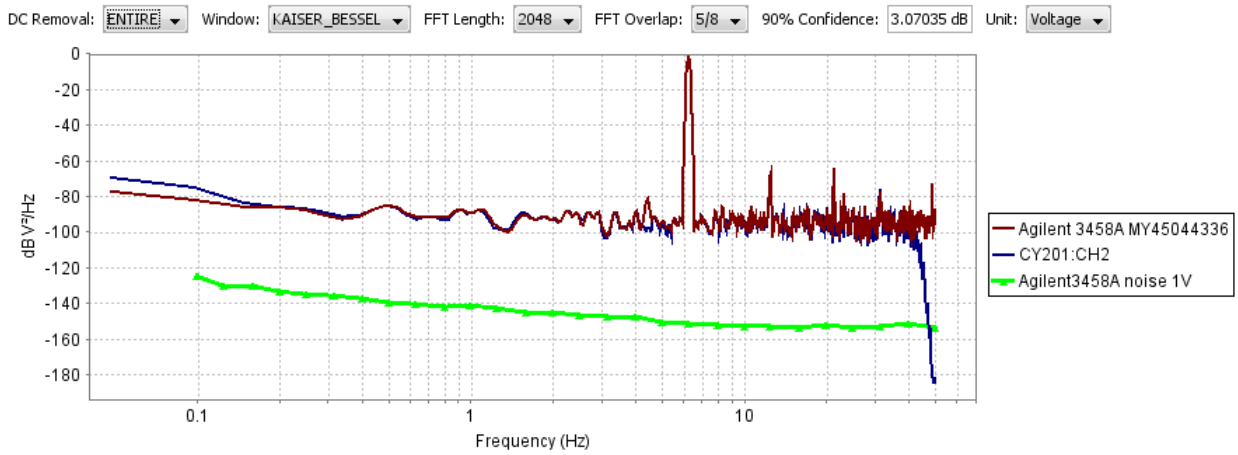


Figure 144 Calibrator Total Harmonic Distortion

Table 32 SHDAS digitizer Calibrator Signal and Monitor Channel THD

Digitizer	Calibration Signal THD	Monitor Channel THD
# 1	-62.46 dB	-62.29 dB
# 2	-65.60 dB	-65.39 dB
# 3	-59.55 dB	-59.38 dB
# 4	-60.85 dB	-60.77 dB
# 5	-66.53 dB	-66.29 dB
# 6	-63.71 dB	-63.45 dB
# 7	-66.31 dB	-66.05 dB
# 8	-62.34 dB	-62.17 dB
# 9	-59.39 dB	-59.16 dB
# 10	-60.32 dB	-60.08 dB
# 11	-63.24 dB	-63.05 dB
# 12	-61.89 dB	-61.77 dB
# 13	-64.92 dB	-64.76 dB
# 14	-65.47 dB	-65.19 dB
# 15	-61.89 dB	-61.74 dB
# 16	-63.20 dB	-63.19 dB
# 17	-62.60 dB	-62.40 dB
# 18	-64.35 dB	-64.20 dB

4.17 Calibrator – PRNG

The SHDAS Calibrator was commanded to generate a PRNG signal at 12 dB for 300 seconds. The SHDAS system generates two PRNG signals: A short duration 100 second signal for high frequency and a longer duration 350 second signal for low frequency.

The PRNG signal was recorded on both the Smart24 at 200 Hz and the CH2 channel of the SHDAS digitizer at 100 Hz. The primary channel of the Smart24 was configured to record at 200 Hz so that the anti-alias filter on the Smart24 would not impact the estimate of the SHDAS response. The SHDAS digitizer data was up-sampled from 100 Hz to 200 Hz using a reconstruction filter that does not add additional frequency content. The results should not be interpreted beyond the original Nyquist frequency of 50 Hz.

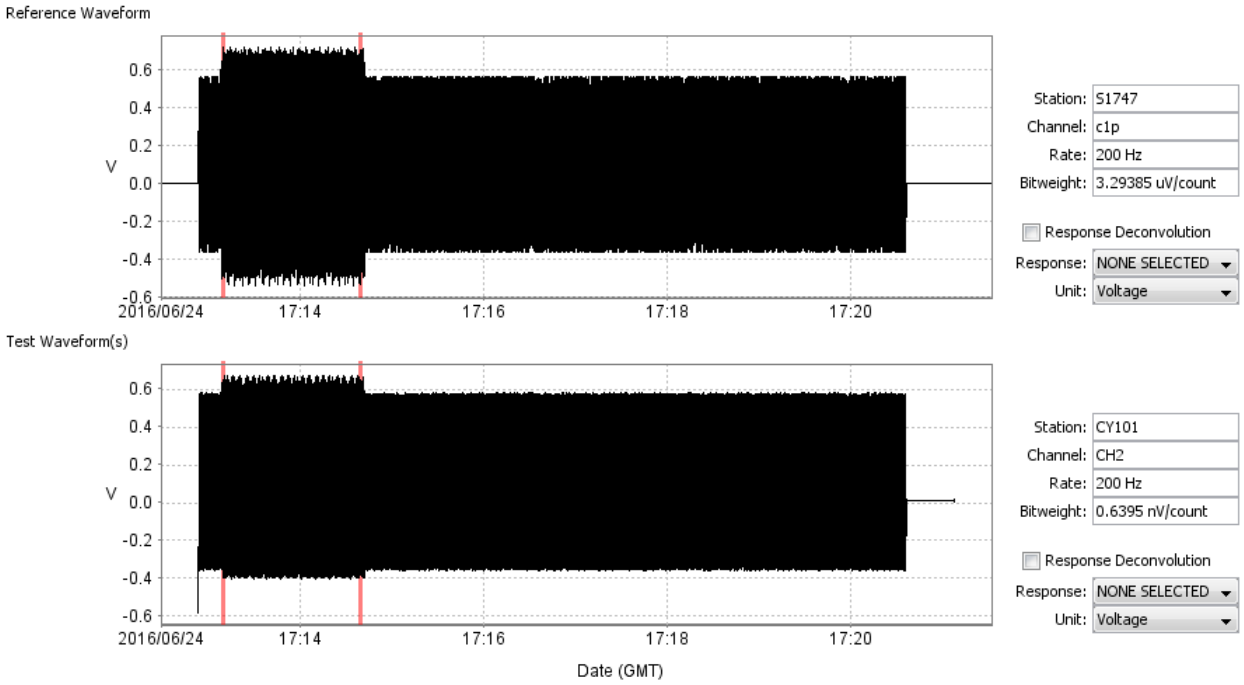


Figure 145 PRNG Time Series

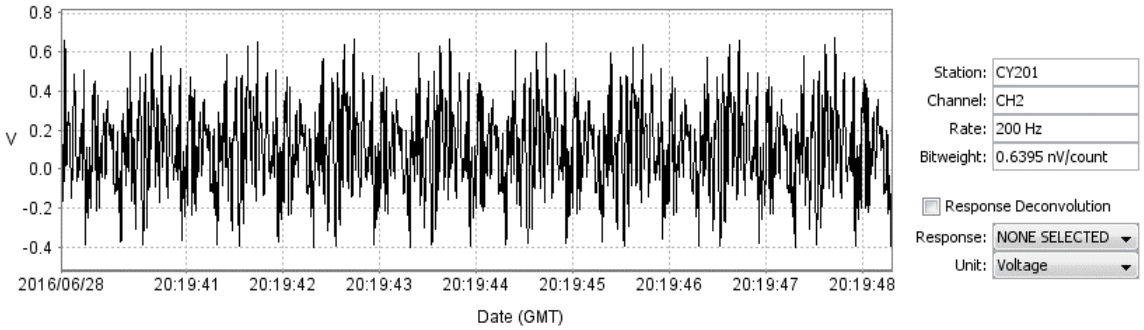


Figure 146 PRNG High Frequency Time Series

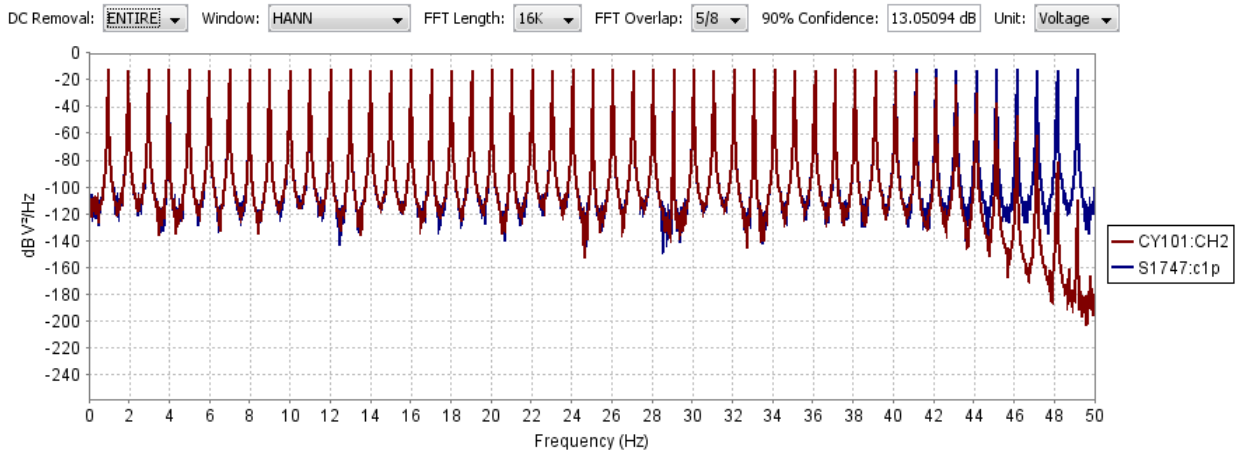


Figure 147 PRNG High Frequency Power Spectra

The high frequency segment of the PRNG sequence was found to have spectral peaks every 1.0039 Hz. The peaks were specifically observed at the following frequencies, rounded to 2 decimal places:

1.00 Hz, 2.01 Hz, 3.01 Hz, 4.02 Hz, 5.02 Hz, 6.02 Hz, 7.03 Hz, 8.03 Hz, 9.04 Hz, 10.04 Hz,
11.04 Hz, 12.05 Hz, 13.05 Hz, 14.05 Hz, 15.06 Hz, 16.06 Hz, 17.07 Hz, 18.07 Hz, 19.07 Hz, 20.08 Hz,
21.08 Hz, 22.09 Hz, 23.09 Hz, 24.09 Hz, 25.10 Hz, 26.10 Hz, 27.11 Hz, 28.11 Hz, 29.11 Hz, 30.12 Hz,
31.12 Hz, 32.12 Hz, 33.13 Hz, 34.13 Hz, 35.14 Hz, 36.14 Hz, 37.14 Hz, 38.15 Hz, 39.15 Hz, 40.16 Hz,
41.16 Hz, 42.16 Hz, 43.17 Hz, 44.17 Hz, 45.18 Hz, 46.18 Hz, 47.18 Hz, 48.19 Hz, 49.19 Hz

The frequency content of the generated PRNG sequence was observed to extend out to the limit of the observable frequency content of the 200 Hz recording channel on the Smart24.

Similar frequency content was observed on the high frequency PRNG sequences for all of the digitizers.

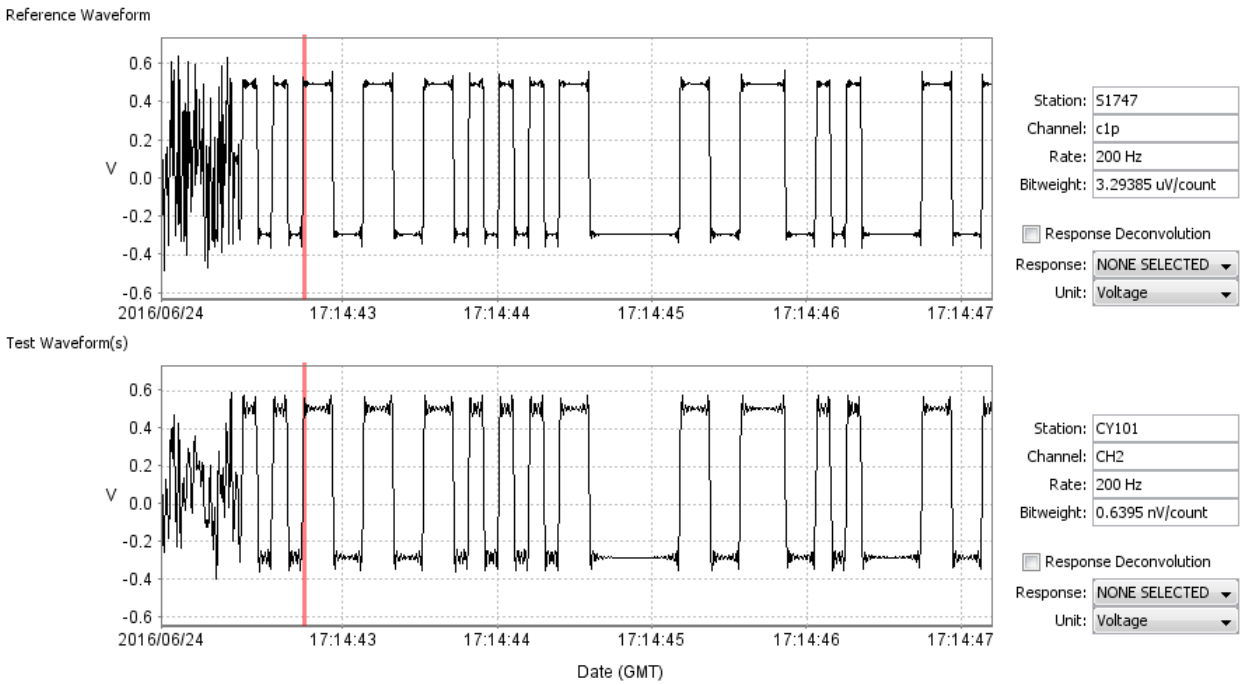


Figure 148 PRNG Low Frequency Time Series

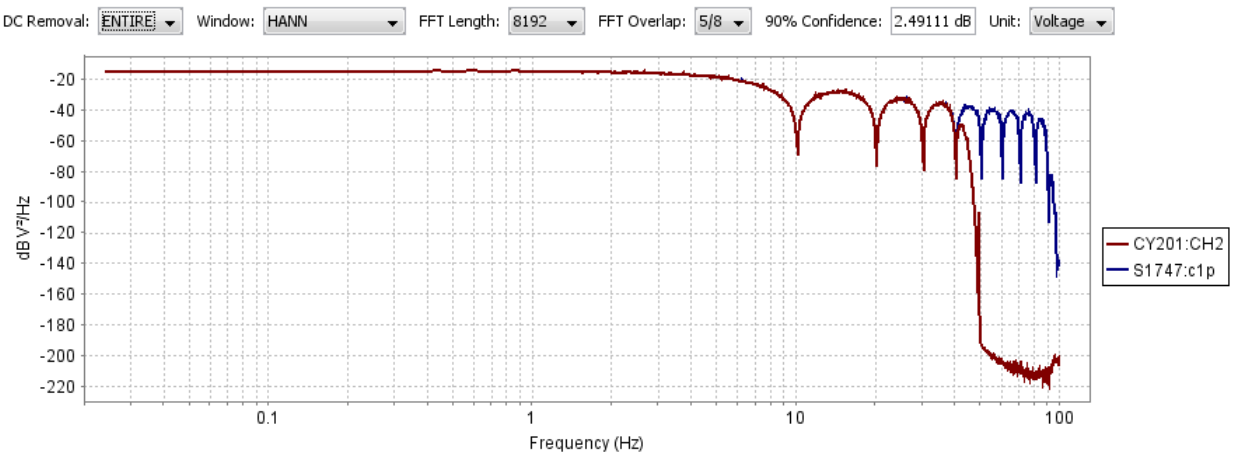


Figure 149 PRNG Low Frequency Power Spectra

The low frequency segment of the PRNG sequence was found to have spectral nulls every 10.24 Hz. The nulls were specifically observed at the following frequencies, rounded to 2 decimal places:

10.24 Hz, 20.48 Hz, 30.72 Hz, 40.96 Hz, 51.20 Hz, 61.44 Hz, 71.68 Hz, 81.92 Hz

The frequency content of the generated PRNG sequence was observed to extend out to the limit of the observable frequency content of the 200 Hz recording channel on the Smart24.

Similar frequency content was observed on the low frequency PRNG sequences for all of the digitizers.

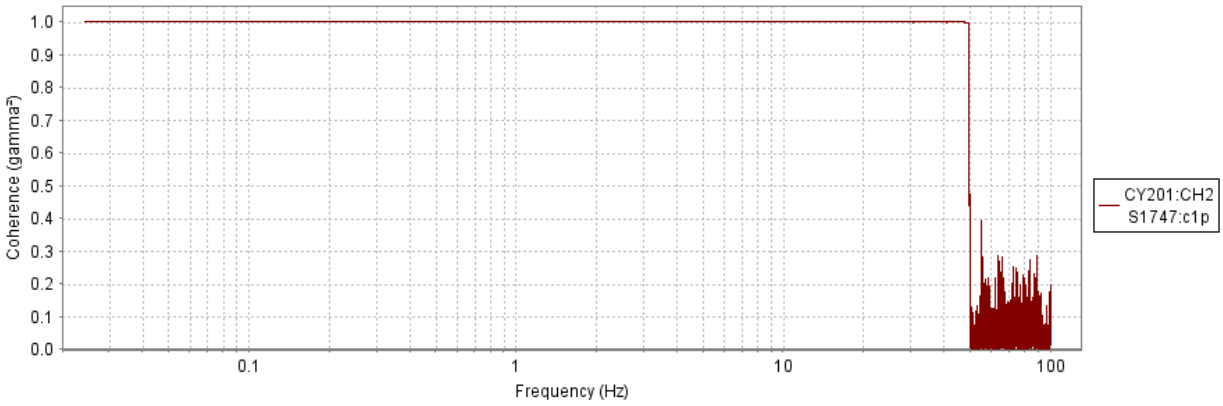


Figure 150 PRNG Low Frequency Coherence

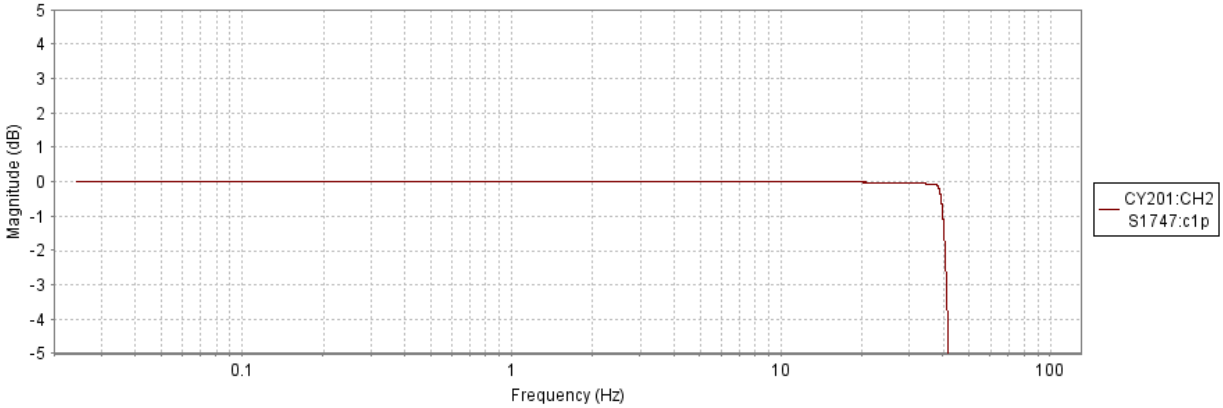


Figure 151 PRNG Low Frequency Relative Amplitude

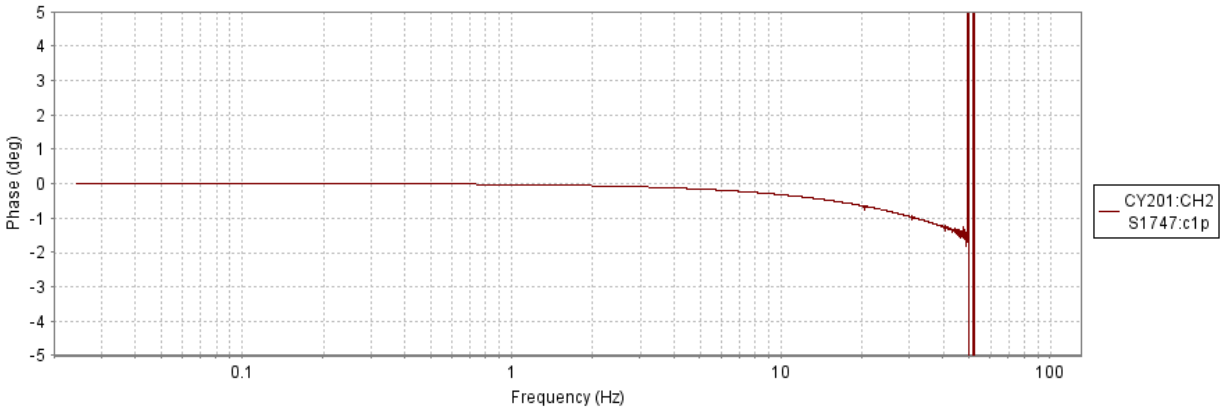


Figure 152 PRNG Low Frequency Relative Phase

Using the low frequency PRNG signal and coherence analysis relative to the Smart24 channel, it is possible to determine the 3 dB passband limits of the Monitor Channel (CH2). The frequency passband of the Monitor Channel spans from 0 Hz up to the high frequency passband limits shown in the table below.

Table 33 SHDAS digitizer Calibrator Monitor Channel Passband

Digitizer	High Frequency
# 1	42.26 Hz
# 2	42.26 Hz
# 3	42.25 Hz
# 4	42.26 Hz
# 5	42.25 Hz
# 6	42.26 Hz
# 7	42.26 Hz
# 8	42.26 Hz
# 9	42.26 Hz
# 10	42.26 Hz
# 11	42.25 Hz
# 12	42.26 Hz
# 13	42.25 Hz
# 14	42.24 Hz
# 15	42.26 Hz
# 16	42.26 Hz
# 17	42.26 Hz
# 18	42.25 Hz

SUMMARY

Input Impedance

Input Impedance was measured for each of the three Broadband and Short-period channels tied together. Typical input impedance for the broadband channels was not measurable due to being in excess of a Gohm which represents the measurement limits of the reference meter. A few of the broadband channels did have a measurable impedance, however even these were on the order of a Gohm as well. Typical input impedance for the shortperiod channel was measured to be approximately 3.5 Mohm with observed values in the range of 3.3 to 3.9 Mohm.

Sensitivity

The average bit weight for the broadband channels was measured to be 0.6971 nV/count with a standard deviation of 0.0012, a minimum of 0.6946 nV/count, and a maximum of 0.6995 nV/count. The average bit weight for the short period channels was measured to be 0.3203 nV/count with a standard deviation of 0.0005, a minimum of 0.3217 nV/count, and a maximum of 0.3195 nV/count.

DC Offset

The average DC offset for the broadband channels was measured to be 11.73 mV with a standard deviation of 0.05 mV, a minimum of 11.60 mV, and a maximum of 11.83 mV. The average DC offset for the short period channels was measured to be 5.39 mV with a standard deviation of 0.06 mV, a minimum of 5.33 mV, and a maximum of 5.75 mV.

Full Scale

All channels were verified to have a full scale that was consistent with the nominal full scale of 2.8 V peak-to-peak on the broadband channels and 1.3 V peak-to-peak on the short-period channels. There were no signs of clipping or flattening of the recorded signal at amplitudes at or near full scale.

Self-Noise / Seismic System Noise

The self-noise level of the digitizers was observed to vary considerably across the units. Several of the units were initially observed to have noise levels that were elevated well above that of the measurements made on the earlier prototypes. The units that were of concern were investigated by Leidos and corrective action taken to remediate the noise levels before re-testing. With no defined requirement, the USAF provided desired guidance that the noise levels should be a minimum of 6 dB below the ocean bottom site noise model across 0.02 – 40 Hz for the broadband channels and 0.5 – 40 Hz for the short-period channels and that the self-noise time series should not contain significantly impacting time-domain transients. All evaluated digitizers were found to meet this guidance.

Dynamic Range

The average dynamic range for the broadband channels was measured to be 125.5 dB with a standard deviation of 2 dB, a minimum of 121 dB, and a maximum of 127.9 dB. The average dynamic range for the short period channels was measured to be 121.7 dB with a standard deviation of 1.24 dB, a maximum of 122.7 dB and a minimum of 115.5 dB.

Response Verification

All of the broadband and short-period channels were found to have response characteristics that are consistent with previously measured sensitivities and the expected nominal responses. Slight variations in the phase response were observed that were attributable to the impact of the timing offset from the prototype SNIB and SNIT in use during production testing.

Passband

The average passband for the broadband channels was measured to be 2.93 Hz to 41.41 Hz. The low frequency limit was observed to vary from 2.88 to 2.98 Hz. The high frequency limit was not observed to vary appreciably. The average passband for the short-period channels was measured to be from 0 Hz to 41.24 Hz. The passband limits for the short-period channels were not observed to vary appreciably.

Linearity

The average linearity for the broadband channels was measured to be -98.74 dB with a standard deviation of 0.35 dB, a minimum of -99.63 dB, and a maximum of -97.95 dB. The average linearity for the short period channels was measured to be -100.73 dB with a standard deviation of 0.48 dB, a minimum of -101.71 dB, and a maximum of -99.73 dB.

Crosstalk

The average crosstalk for the broadband channels was measured to be -135.74 dB with a standard deviation of 2.07 dB, a minimum of -139.17 dB, and a maximum of -131.89 dB. The average crosstalk for the short period channels was measured to be -112.17 dB with a standard deviation of 5.36 dB, a minimum of -127.3 dB, and a maximum of -101.68 dB.

Timing Accuracy

Preliminary timing accuracy measurements were made on the ePVs during production testing. However, these measurements were made using a prototype SNIB and SNIT. It was found that the SNIB and SNIT were affecting the results of the timing testing. Further timing tests were performed during system integration in which it was found that the ePVs have a baseline timing offset of approximately 350 microseconds and that there was a predictable timing delay due to the speed of propagation in the fiber cable. In addition, it was demonstrated that the shore station can be programmed to shift the timing signal to the ePVs so as to cancel out the observable timing offset.

Calibrator Sensitivity

The average sensitivity of the calibrator monitor channel was measured to be 0.6393 nV/count with a standard deviation of 0.0011 nV/count, a minimum of 0.6374 nV/count, and a maximum of 0.6411 nV/count.

Calibrator Linearity

The average linearity of the signal generated by the calibrator was measured to be -63.03 dB with a standard deviation of 2.2 dB, a minimum of -66.53 dB, and a maximum of -59.39 dB. The average linearity of the calibrator signal on the calibrator monitor channel was measured to be -62.85 dB with a standard deviation of 2.25 dB, a minimum of –66.29 dB, and a maximum of -59.16 dB. The calibrator monitor channel does not appear to add any significant level of signal distortion than is already present in the generated calibrator signal.

Calibrator PRNG

The characteristics of the PRNG signal generated by the calibrator were consistent between all digitizer units that were evaluated. The low frequency segment of the PRNG sequence has null points in the power spectra every 10.24 Hz. The high frequency segment of the PRNG sequence has peaks in the power spectra every 1.0039 Hz. Using the PRNG sequence to evaluate the monitor channel, the upper limit to the monitor channel passband is approximately 42.26 Hz.

REFERENCES

1. Holcomb, Gary L. (1989), *A Direct Method for calculating Instrument Noise Levels in Side-by-Side Seismometer Evaluations*, DOI USGS Open-File Report 89-214.

2. IEEE Standard for Digitizing Waveform Recorders, IEEE Std. 1057-1994.

3. IEEE Standard for Analog to Digital Converters, IEEE Std. 1241-2010.

4. Kromer, Richard P., Hart, Darren M. and J. Mark Harris (2007), *Test Definition for the Evaluation of Digital Waveform Recorders Version 1.0*, SAND2007-5037.

5. McDonald, Timothy S. (1994), *Modified Noise Power Ratio Testing of High Resolution digitizers*, SAND94-0221.

6. Merchant, B. John, and Darren M. Hart (2011), *Component Evaluation Testing and Analysis Algorithms*, SAND2011-8265.

7. Sleeman, R., Wettum, A., Trampert, J. (2006), *Three-Channel Correlation Analysis: A New Technique to Measure Instrumental Noise of Digitizers and Seismic Sensors*, Bulletin of the Seismological Society of America, Vol. 96, No. 1, pp. 258-271, February 2006.

APPENDIX A: AMPLITUDE AND PHASE RESPONSE

The following tables provide the empirical amplitude and phase corrections for each digitizer channel. The corrections were determined by measuring the relative amplitude and phase response for a band-limited white noise signal recorded simultaneously on each digitizer channel and a reference Geotech Smart24 digitizer. The amplitude is expressed in dB relative to the empirical bit-weights in Table 7 Small Signal 10 Hz Sensitivity. The phase is expressed in degrees.

The uncertainty in the measured values is a function of the coherence and the uncertainty of the response characteristics of the reference digitizer. The broadband channels on the SHDAS digitizer were observed to have reduced coherence of below 0.9 at frequencies below 0.03 Hz due to the presence of a high-pass filter with a 3 dB corner at 2.93 Hz that reduced the signal amplitude below the measurement noise floor.

Digitizer #1

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.2390	88.1790	-25.2334	87.0590	-24.6438	78.0606						
0.0125	-23.3650	88.7468	-23.6650	87.5100	-23.5009	84.0514						
0.0160	-22.7113	88.1790	-23.0550	89.5120	-22.9245	88.9439						
0.0200	-21.2980	88.9677	-21.3132	89.5120	-21.3106	89.5763						
0.0250	-21.1051	88.9481	-20.9691	89.4964	-20.8835	89.5240						
0.0315	-19.6647	88.8638	-19.6771	89.2446	-19.6149	89.2344						
0.0400	-18.8767	88.7515	-18.9052	88.9568	-18.8477	89.2302						
0.0500	-17.7476	88.7497	-17.8366	88.9538	-17.8210	89.1735						
0.0630	-16.7856	88.7138	-16.8416	88.8287	-16.8052	88.7479						
0.0800	-15.8202	88.5463	-15.8946	88.4513	-15.8738	88.3837						
0.1000	-14.8518	88.1291	-14.9243	88.1404	-14.9001	88.1338	0.0011	-0.0039	0.0012	-0.0042	0.0012	-0.0041
0.1250	-13.9542	87.7171	-14.0224	87.7336	-13.9945	87.7585	0.0010	-0.0034	0.0011	-0.0042	0.0012	-0.0038
0.1600	-12.8107	87.0512	-12.8770	87.0815	-12.8538	87.0764	0.0010	-0.0040	0.0011	-0.0045	0.0012	-0.0042
0.2000	-11.8556	86.2491	-11.9225	86.3642	-11.8888	86.3661	0.0010	-0.0040	0.0011	-0.0048	0.0012	-0.0045
0.2500	-10.8898	85.4620	-10.9613	85.5236	-10.9299	85.5059	0.0010	-0.0073	0.0011	-0.0071	0.0012	-0.0069
0.3150	-9.8799	84.2559	-9.9448	84.3226	-9.9209	84.3155	0.0010	-0.0088	0.0011	-0.0096	0.0012	-0.0092
0.4000	-8.8498	82.7379	-8.9172	82.8459	-8.8908	82.8266	0.0010	-0.0118	0.0011	-0.0131	0.0011	-0.0126
0.5000	-7.9117	81.0021	-7.9777	81.1631	-7.9510	81.1051	0.0009	-0.0150	0.0010	-0.0159	0.0011	-0.0151
0.6300	-6.9391	78.7511	-7.0036	78.9416	-6.9769	78.8675	0.0008	-0.0191	0.0009	-0.0211	0.0010	-0.0191
0.8000	-5.9463	75.8376	-6.0087	76.0823	-5.9831	75.9904	0.0008	-0.0263	0.0009	-0.0288	0.0009	-0.0270
1.0000	-5.0430	72.5028	-5.1030	72.7960	-5.0779	72.6829	0.0007	-0.0296	0.0008	-0.0326	0.0008	-0.0303
1.2500	-4.1916	68.5802	-4.2481	68.9229	-4.2248	68.7901	0.0006	-0.0387	0.0008	-0.0430	0.0008	-0.0400
1.6000	-3.2989	63.4012	-3.3498	63.8054	-3.3282	63.6388	0.0006	-0.0461	0.0008	-0.0518	0.0008	-0.0479
2.0000	-2.5592	57.9539	-2.6042	58.4003	-2.5852	58.2147	0.0008	-0.0601	0.0010	-0.0669	0.0010	-0.0623
2.5000	-1.9083	51.9924	-1.9460	52.4702	-1.9299	52.2707	0.0015	-0.0748	0.0016	-0.0833	0.0017	-0.0778
3.1500	-1.3360	45.4350	-1.3652	45.9247	-1.3526	45.7172	0.0028	-0.0925	0.0030	-0.1037	0.0031	-0.0970
4.0000	-0.8661	38.6139	-0.8869	39.0904	-0.8779	38.8855	0.0035	-0.1193	0.0036	-0.1327	0.0037	-0.1236
5.0000	-0.5365	32.5477	-0.5501	32.9902	-0.5442	32.7976	0.0021	-0.1479	0.0022	-0.1643	0.0023	-0.1531
6.3000	-0.2894	26.8115	-0.2971	27.2071	-0.2937	27.0324	0.0000	-0.1861	0.0001	-0.2067	0.0002	-0.1926
8.0000	-0.1112	21.6081	-0.1143	21.9509	-0.1129	21.7968	-0.0003	-0.2365	-0.0002	-0.2622	-0.0001	-0.2449
10.0000	0.0010	17.4579	0.0009	17.7530	0.0009	17.6164	-0.0007	-0.2948	-0.0006	-0.3281	-0.0005	-0.3060
12.5000	0.0763	13.9550	0.0784	14.2103	0.0775	14.0874	-0.0005	-0.3687	-0.0004	-0.4100	-0.0003	-0.3818
16.0000	0.1252	10.7641	0.1288	10.9836	0.1272	10.8720	-0.0052	-0.4689	-0.0052	-0.5217	-0.0050	-0.4864
20.0000	0.1532	8.3798	0.1578	8.5768	0.1558	8.4701	-0.0081	-0.5835	-0.0082	-0.6494	-0.0079	-0.6055
25.0000	0.1662	6.3782	0.1715	6.5614	0.1691	6.4551	-0.0148	-0.7242	-0.0151	-0.8061	-0.0147	-0.7516
31.5000	0.1712	4.6261	0.1771	4.8036	0.1744	4.6925	-0.0230	-0.9063	-0.0234	-1.0096	-0.0229	-0.9409
40.0000	-0.2907	3.0840	-0.2843	3.2645	-0.2873	3.1422	-0.4894	-1.1328	-0.4902	-1.2636	-0.4895	-1.1764

Digitizer #2

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.7083	86.7566	-25.0146	83.9259	-23.9868	89.5977						
0.0125	-23.2619	89.1323	-23.1976	87.0516	-23.3195	89.1369						
0.0160	-22.5700	87.8681	-22.6410	87.0516	-22.9012	89.5111						
0.0200	-21.2255	88.9367	-21.1713	87.4763	-21.4403	89.5111						
0.0250	-21.0345	89.1323	-20.9183	87.4989	-21.1680	89.5111						
0.0315	-19.5011	88.9367	-19.4946	88.1783	-19.6097	89.5111						
0.0400	-18.8004	89.1323	-18.7714	88.7704	-18.8389	89.3876						
0.0500	-17.7091	88.9367	-17.7015	88.8700	-17.7179	88.7916						
0.0630	-16.6879	88.8367	-16.7067	88.7704	-16.7306	88.5647						
0.0800	-15.7603	88.4634	-15.7675	88.3495	-15.7596	88.2302						
0.1000	-14.7797	88.1990	-14.7931	88.1226	-14.7918	88.0107	0.0031	-0.0006	0.0030	-0.0005	0.0031	0.0001
0.1250	-13.8854	87.4125	-13.9136	87.7110	-13.8779	87.5198	0.0030	-0.0013	0.0030	-0.0006	0.0030	-0.0011
0.1600	-12.7360	87.0195	-12.7528	86.9239	-12.7493	87.0188	0.0031	-0.0026	0.0030	-0.0024	0.0031	-0.0020
0.2000	-11.7849	86.1538	-11.7976	86.2529	-11.7924	86.2144	0.0031	-0.0047	0.0030	-0.0039	0.0031	-0.0041
0.2500	-10.8155	85.3169	-10.8294	85.2994	-10.8267	85.3494	0.0030	-0.0112	0.0030	-0.0096	0.0030	-0.0106
0.3150	-9.8002	84.1793	-9.8169	84.1641	-9.8054	84.2217	0.0030	-0.0123	0.0029	-0.0113	0.0030	-0.0123
0.4000	-8.7751	82.5791	-8.7910	82.6251	-8.7869	82.6364	0.0029	-0.0143	0.0029	-0.0125	0.0029	-0.0137
0.5000	-7.8387	80.8417	-7.8534	80.8971	-7.8506	80.8890	0.0029	-0.0158	0.0028	-0.0141	0.0028	-0.0152
0.6300	-6.8672	78.5384	-6.8814	78.6114	-6.8775	78.5996	0.0028	-0.0227	0.0027	-0.0199	0.0028	-0.0211
0.8000	-5.8748	75.5898	-5.8876	75.6603	-5.8833	75.6598	0.0026	-0.0262	0.0026	-0.0233	0.0027	-0.0255
1.0000	-4.9732	72.2120	-4.9858	72.2972	-4.9811	72.2933	0.0026	-0.0344	0.0026	-0.0297	0.0026	-0.0333
1.2500	-4.1254	68.2269	-4.1367	68.3220	-4.1321	68.3153	0.0024	-0.0404	0.0024	-0.0354	0.0024	-0.0392
1.6000	-3.2382	62.9199	-3.2477	63.0206	-3.2428	62.9991	0.0025	-0.0530	0.0025	-0.0465	0.0026	-0.0519
2.0000	-2.5041	57.4560	-2.5120	57.5644	-2.5078	57.5425	0.0029	-0.0644	0.0029	-0.0570	0.0029	-0.0624
2.5000	-1.8614	51.4554	-1.8677	51.5659	-1.8639	51.5343	0.0035	-0.0850	0.0035	-0.0746	0.0035	-0.0824
3.1500	-1.2991	44.8636	-1.3036	44.9713	-1.3004	44.9328	0.0049	-0.1055	0.0049	-0.0931	0.0048	-0.1031
4.0000	-0.8391	38.0406	-0.8422	38.1407	-0.8400	38.1005	0.0054	-0.1340	0.0054	-0.1179	0.0054	-0.1301
5.0000	-0.5182	32.0172	-0.5201	32.1090	-0.5185	32.0694	0.0042	-0.1680	0.0041	-0.1476	0.0042	-0.1628
6.3000	-0.2783	26.3221	-0.2793	26.4051	-0.2783	26.3683	0.0019	-0.2119	0.0019	-0.1866	0.0019	-0.2057
8.0000	-0.1075	21.1895	-0.1078	21.2682	-0.1074	21.2340	0.0015	-0.2701	0.0015	-0.2379	0.0015	-0.2622
10.0000	0.0007	17.1009	0.0007	17.1733	0.0007	17.1449	0.0011	-0.3334	0.0011	-0.2934	0.0011	-0.3244
12.5000	0.0737	13.6445	0.0740	13.7170	0.0737	13.6925	0.0015	-0.4178	0.0016	-0.3684	0.0015	-0.4070
16.0000	0.1200	10.5062	0.1205	10.5807	0.1200	10.5597	-0.0033	-0.5321	-0.0032	-0.4686	-0.0033	-0.5171
20.0000	0.1466	8.1571	0.1472	8.2385	0.1466	8.2204	-0.0063	-0.6616	-0.0061	-0.5827	-0.0062	-0.6427
25.0000	0.1587	6.1810	0.1595	6.2733	0.1587	6.2567	-0.0132	-0.8227	-0.0127	-0.7238	-0.0131	-0.7997
31.5000	0.1631	4.4536	0.1641	4.5603	0.1633	4.5462	-0.0215	-1.0318	-0.0208	-0.9072	-0.0214	-1.0018
40.0000	-0.2994	2.9167	-0.2980	3.0461	-0.2989	3.0317	-0.4886	-1.2907	-0.4876	-1.1330	-0.4884	-1.2529

Digitizer #3

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-26.5460	92.3348	-26.0060	94.8002	-26.1259	91.0958						
0.0125	-23.6145	90.4684	-23.3140	90.9191	-23.5696	89.9919						
0.0160	-22.7016	90.2792	-22.5569	90.6983	-22.6076	89.2895						
0.0200	-21.2898	89.0636	-21.1684	89.4748	-21.2663	89.1735						
0.0250	-20.9871	88.9907	-20.9201	89.4695	-20.9743	89.1735						
0.0315	-19.5457	88.9246	-19.5416	89.0030	-19.5861	89.0242						
0.0400	-18.7541	88.9104	-18.7790	88.8946	-18.7943	88.9610						
0.0500	-17.7134	88.7175	-17.7064	88.8351	-17.6881	88.9318						
0.0630	-16.7275	88.6844	-16.7208	88.6630	-16.6905	88.8262						
0.0800	-15.7703	88.4723	-15.7713	88.5033	-15.7601	88.5593						
0.1000	-14.8145	88.0198	-14.8019	88.0314	-14.7946	87.9651	0.0005	-0.0041	0.0005	-0.0044	0.0005	-0.0044
0.1250	-13.9069	87.6199	-13.8981	87.6798	-13.8892	87.6188	0.0004	-0.0041	0.0004	-0.0044	0.0004	-0.0045
0.1600	-12.7726	86.9597	-12.7558	87.0347	-12.7512	86.9474	0.0005	-0.0062	0.0005	-0.0060	0.0005	-0.0072
0.2000	-11.8149	86.3299	-11.7909	86.3288	-11.7987	86.2540	0.0005	-0.0071	0.0005	-0.0069	0.0005	-0.0076
0.2500	-10.8508	85.3674	-10.8229	85.3733	-10.8278	85.3846	0.0005	-0.0074	0.0005	-0.0070	0.0005	-0.0078
0.3150	-9.8373	84.2660	-9.8149	84.2514	-9.8161	84.1656	0.0005	-0.0085	0.0005	-0.0081	0.0005	-0.0094
0.4000	-8.8103	82.6833	-8.7905	82.6654	-8.7918	82.6304	0.0006	-0.0093	0.0006	-0.0094	0.0006	-0.0106
0.5000	-7.8716	80.9442	-7.8533	80.9331	-7.8549	80.8990	0.0005	-0.0113	0.0005	-0.0111	0.0005	-0.0128
0.6300	-6.8981	78.6773	-6.8784	78.6539	-6.8817	78.6183	0.0005	-0.0189	0.0005	-0.0192	0.0005	-0.0210
0.8000	-5.9042	75.7354	-5.8841	75.6883	-5.8885	75.6616	0.0004	-0.0240	0.0004	-0.0244	0.0004	-0.0268
1.0000	-5.0017	72.3795	-4.9825	72.3238	-4.9870	72.3030	0.0003	-0.0285	0.0003	-0.0290	0.0003	-0.0314
1.2500	-4.1519	68.3974	-4.1336	68.3156	-4.1378	68.3075	0.0002	-0.0385	0.0002	-0.0390	0.0002	-0.0428
1.6000	-3.2613	63.1750	-3.2431	63.0744	-3.2483	63.0717	0.0004	-0.0472	0.0004	-0.0476	0.0004	-0.0527
2.0000	-2.5239	57.6982	-2.5087	57.5731	-2.5128	57.5862	0.0006	-0.0602	0.0006	-0.0610	0.0006	-0.0668
2.5000	-1.8782	51.6907	-1.8649	51.5462	-1.8688	51.5722	0.0013	-0.0732	0.0013	-0.0743	0.0013	-0.0813
3.1500	-1.3112	45.1005	-1.3006	44.9461	-1.3039	44.9814	0.0024	-0.0927	0.0024	-0.0931	0.0024	-0.1028
4.0000	-0.8483	38.2627	-0.8407	38.1104	-0.8431	38.1494	0.0031	-0.1185	0.0032	-0.1201	0.0031	-0.1316
5.0000	-0.5244	32.2176	-0.5193	32.0730	-0.5211	32.1172	0.0019	-0.1496	0.0020	-0.1512	0.0019	-0.1661
6.3000	-0.2824	26.5124	-0.2793	26.3815	-0.2804	26.4258	-0.0003	-0.1839	-0.0003	-0.1861	-0.0004	-0.2047
8.0000	-0.1093	21.3449	-0.1081	21.2321	-0.1086	21.2755	-0.0008	-0.2377	-0.0007	-0.2406	-0.0008	-0.2640
10.0000	-0.0002	17.2552	-0.0002	17.1590	-0.0002	17.2032	-0.0010	-0.2932	-0.0010	-0.2963	-0.0011	-0.3265
12.5000	0.0731	13.7937	0.0723	13.7141	0.0726	13.7577	-0.0008	-0.3663	-0.0007	-0.3704	-0.0009	-0.4075
16.0000	0.1205	10.6390	0.1192	10.5741	0.1195	10.6218	-0.0055	-0.4681	-0.0054	-0.4734	-0.0056	-0.5212
20.0000	0.1474	8.2939	0.1457	8.2404	0.1463	8.2917	-0.0082	-0.5845	-0.0082	-0.5916	-0.0085	-0.6508
25.0000	0.1601	6.3291	0.1580	6.2833	0.1589	6.3420	-0.0149	-0.7237	-0.0150	-0.7325	-0.0154	-0.8062
31.5000	0.1646	4.6192	0.1625	4.5810	0.1634	4.6493	-0.0231	-0.9013	-0.0232	-0.9124	-0.0238	-1.0054
40.0000	-0.2974	3.1059	-0.2996	3.0739	-0.2985	3.1554	-0.4894	-1.1327	-0.4895	-1.1463	-0.4905	-1.2638

Digitizer #4

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.0584	83.7901	-25.3253	101.2218	-25.0457	90.5021						
0.0125	-23.3821	89.9971	-23.7454	91.4009	-23.2619	90.5021						
0.0160	-22.7988	89.9707	-22.9173	89.5218	-22.9539	90.2462						
0.0200	-21.2725	89.4351	-21.3203	89.2932	-21.3004	89.8623						
0.0250	-20.9678	89.4351	-21.0464	89.2226	-21.0280	89.8011						
0.0315	-19.6112	89.1200	-19.6481	89.1541	-19.7212	89.7540						
0.0400	-18.8231	89.1133	-18.9061	89.0931	-18.8720	89.1985						
0.0500	-17.7339	89.0713	-17.7993	88.9920	-17.7763	88.9550						
0.0630	-16.7710	88.7847	-16.8437	88.9147	-16.8118	88.8331						
0.0800	-15.8014	88.5701	-15.8823	88.5374	-15.8378	88.4858						
0.1000	-14.8314	88.1359	-14.9103	88.1306	-14.8695	88.2042	0.0017	-0.0023	0.0016	-0.0016	0.0018	-0.0026
0.1250	-13.9266	87.6729	-14.0125	87.7837	-13.9672	87.7362	0.0017	-0.0034	0.0016	-0.0028	0.0017	-0.0038
0.1600	-12.7870	87.0582	-12.8691	87.1032	-12.8183	87.1215	0.0017	-0.0046	0.0016	-0.0044	0.0018	-0.0051
0.2000	-11.8319	86.2522	-11.9138	86.3464	-11.8617	86.3749	0.0017	-0.0062	0.0016	-0.0060	0.0017	-0.0061
0.2500	-10.8633	85.4332	-10.9443	85.4976	-10.8962	85.4900	0.0018	-0.0089	0.0017	-0.0078	0.0018	-0.0095
0.3150	-9.8574	84.2561	-9.9344	84.3578	-9.8878	84.2797	0.0017	-0.0106	0.0016	-0.0105	0.0018	-0.0119
0.4000	-8.8261	82.7194	-8.9048	82.8581	-8.8573	82.7651	0.0018	-0.0127	0.0016	-0.0123	0.0018	-0.0141
0.5000	-7.8884	80.9568	-7.9661	81.1118	-7.9200	81.0258	0.0018	-0.0144	0.0017	-0.0134	0.0018	-0.0161
0.6300	-6.9155	78.6887	-6.9931	78.8936	-6.9469	78.7754	0.0017	-0.0193	0.0016	-0.0185	0.0017	-0.0215
0.8000	-5.9232	75.7603	-5.9983	76.0185	-5.9530	75.8690	0.0016	-0.0250	0.0015	-0.0242	0.0017	-0.0280
1.0000	-5.0206	72.4067	-5.0933	72.7287	-5.0500	72.5404	0.0016	-0.0278	0.0014	-0.0264	0.0016	-0.0311
1.2500	-4.1712	68.4578	-4.2404	68.8471	-4.1988	68.6137	0.0015	-0.0369	0.0014	-0.0346	0.0015	-0.0412
1.6000	-3.2784	63.2288	-3.3413	63.6902	-3.3034	63.4121	0.0015	-0.0481	0.0014	-0.0456	0.0015	-0.0541
2.0000	-2.5426	57.7958	-2.5988	58.3163	-2.5649	58.0060	0.0018	-0.0578	0.0017	-0.0549	0.0018	-0.0647
2.5000	-1.8943	51.8181	-1.9418	52.3827	-1.9129	52.0415	0.0024	-0.0727	0.0023	-0.0690	0.0025	-0.0814
3.1500	-1.3259	45.2568	-1.3632	45.8420	-1.3404	45.4846	0.0038	-0.0907	0.0037	-0.0861	0.0038	-0.1018
4.0000	-0.8592	38.4478	-0.8859	39.0204	-0.8695	38.6680	0.0043	-0.1171	0.0042	-0.1115	0.0043	-0.1311
5.0000	-0.5321	32.3971	-0.5499	32.9308	-0.5389	32.5985	0.0031	-0.1466	0.0029	-0.1398	0.0031	-0.1644
6.3000	-0.2870	26.6770	-0.2971	27.1518	-0.2909	26.8514	0.0009	-0.1841	0.0008	-0.1753	0.0009	-0.2070
8.0000	-0.1108	21.4982	-0.1148	21.9031	-0.1123	21.6414	0.0006	-0.2358	0.0005	-0.2241	0.0006	-0.2639
10.0000	0.0001	17.3839	0.0000	17.7239	0.0000	17.4974	0.0002	-0.2929	0.0001	-0.2785	0.0002	-0.3276
12.5000	0.0751	13.9002	0.0779	14.1805	0.0761	13.9857	0.0004	-0.3658	0.0004	-0.3473	0.0004	-0.4093
16.0000	0.1234	10.7295	0.1283	10.9516	0.1252	10.7850	-0.0042	-0.4649	-0.0042	-0.4407	-0.0043	-0.5205
20.0000	0.1511	8.3604	0.1572	8.5386	0.1533	8.3916	-0.0071	-0.5778	-0.0072	-0.5487	-0.0074	-0.6474
25.0000	0.1642	6.3794	0.1711	6.5206	0.1666	6.3867	-0.0138	-0.7189	-0.0138	-0.6814	-0.0142	-0.8058
31.5000	0.1693	4.6523	0.1767	4.7631	0.1717	4.6358	-0.0219	-0.8981	-0.0218	-0.8513	-0.0225	-1.0075
40.0000	-0.2926	3.1299	-0.2849	3.2137	-0.2903	3.0870	-0.4882	-1.1214	-0.4879	-1.0622	-0.4892	-1.2599

Digitizer #5

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	0.0050	89.3399	-25.4226	89.5843	-25.4972	91.9021						
0.0125	0.0063	89.7536	-23.4976	89.7901	-23.4052	89.9169						
0.0160	0.0080	89.7166	-22.9734	89.5843	-22.8755	89.9169						
0.0200	0.0100	89.3399	-21.3715	89.2520	-21.3121	89.6838						
0.0250	0.0125	89.2897	-21.0837	89.2284	-21.0214	89.6544						
0.0315	0.0158	89.2292	-19.6797	89.1718	-19.6379	89.6240						
0.0400	0.0200	89.1038	-18.8887	89.1343	-18.8391	89.3592						
0.0500	0.0250	89.0842	-17.7992	89.0284	-17.7532	89.0839						
0.0630	0.0315	88.7260	-16.8227	88.7051	-16.7798	88.7571						
0.0800	0.0400	88.5296	-15.8632	88.5369	-15.8251	88.5735						
0.1000	0.0500	88.1538	-14.8999	88.1408	-14.8538	88.1487	0.0026	-0.0041	0.0025	-0.0032	0.0026	-0.0039
0.1250	0.0625	87.6245	-14.0008	87.6558	-13.9551	87.5370	0.0023	-0.0041	0.0023	-0.0032	0.0023	-0.0039
0.1600	0.0800	87.0320	-12.8563	86.9993	-12.8118	87.0070	0.0023	-0.0059	0.0023	-0.0047	0.0023	-0.0055
0.2000	0.1000	86.3326	-11.9004	86.2936	-11.8564	86.2549	0.0023	-0.0060	0.0022	-0.0053	0.0023	-0.0056
0.2500	0.1250	85.4875	-10.9402	85.4375	-10.8957	85.4155	0.0023	-0.0091	0.0022	-0.0073	0.0023	-0.0086
0.3150	0.1575	84.3144	-9.9263	84.2218	-9.8823	84.2891	0.0023	-0.0108	0.0022	-0.0086	0.0023	-0.0103
0.4000	0.2000	82.8177	-8.8931	82.7402	-8.8502	82.7982	0.0023	-0.0132	0.0022	-0.0108	0.0023	-0.0124
0.5000	0.2500	81.0846	-7.9541	81.0002	-7.9117	81.0688	0.0023	-0.0176	0.0022	-0.0145	0.0023	-0.0168
0.6300	0.3150	78.8548	-6.9827	78.7405	-6.9417	78.8223	0.0022	-0.0213	0.0021	-0.0173	0.0022	-0.0204
0.8000	0.4000	75.9873	-5.9881	75.8494	-5.9476	75.9614	0.0021	-0.0273	0.0020	-0.0222	0.0021	-0.0255
1.0000	0.5000	72.6709	-5.0833	72.5000	-5.0440	72.6287	0.0021	-0.0343	0.0020	-0.0281	0.0021	-0.0326
1.2500	0.6250	68.7989	-4.2304	68.5984	-4.1926	68.7377	0.0021	-0.0426	0.0020	-0.0344	0.0021	-0.0404
1.6000	0.8000	63.6495	-3.3336	63.4082	-3.2990	63.5815	0.0021	-0.0544	0.0020	-0.0437	0.0021	-0.0520
2.0000	1.0000	58.2510	-2.5902	57.9747	-2.5591	58.1691	0.0024	-0.0676	0.0023	-0.0545	0.0023	-0.0645
2.5000	1.2500	52.3074	-1.9344	52.0030	-1.9077	52.2076	0.0030	-0.0849	0.0029	-0.0692	0.0030	-0.0809
3.1500	1.5750	45.7648	-1.3570	45.4466	-1.3357	45.6542	0.0043	-0.1057	0.0042	-0.0853	0.0043	-0.1011
4.0000	2.0000	38.9346	-0.8813	38.6204	-0.8658	38.8196	0.0049	-0.1339	0.0047	-0.1084	0.0049	-0.1278
5.0000	2.5000	32.8487	-0.5465	32.5508	-0.5361	32.7356	0.0036	-0.1693	0.0035	-0.1368	0.0036	-0.1610
6.3000	3.1500	27.0745	-0.2957	26.8072	-0.2896	26.9691	0.0015	-0.2125	0.0014	-0.1722	0.0014	-0.2025
8.0000	4.0000	21.8441	-0.1134	21.6135	-0.1110	21.7494	0.0011	-0.2718	0.0010	-0.2198	0.0010	-0.2587
10.0000	5.0000	17.6603	0.0005	17.4651	0.0006	17.5765	0.0006	-0.3371	0.0006	-0.2727	0.0006	-0.3211
12.5000	6.2500	14.1333	0.0776	13.9721	0.0759	14.0590	0.0009	-0.4204	0.0010	-0.3398	0.0009	-0.4004
16.0000	8.0000	10.9078	0.1276	10.7796	0.1246	10.8430	-0.0039	-0.5364	-0.0038	-0.4333	-0.0039	-0.5109
20.0000	10.0000	8.5014	0.1562	8.3989	0.1525	8.4429	-0.0069	-0.6687	-0.0066	-0.5397	-0.0068	-0.6369
25.0000	12.5000	6.4869	0.1699	6.4051	0.1657	6.4316	-0.0138	-0.8318	-0.0132	-0.6704	-0.0136	-0.7915
31.5000	15.7500	4.7333	0.1753	4.6713	0.1707	4.6804	-0.0222	-1.0386	-0.0212	-0.8359	-0.0220	-0.9883
40.0000	20.0000	3.1878	-0.2866	3.1426	-0.2914	3.1336	-0.4891	-1.3012	-0.4874	-1.0455	-0.4888	-1.2376

Digitizer #6

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.5130	90.8110	-25.4219	89.9191	-25.3486	90.1872						
0.0125	-23.4432	89.9628	-23.3751	89.8250	-23.4575	89.7406						
0.0160	-22.8708	89.8025	-22.7917	89.7942	-22.8972	89.3536						
0.0200	-21.3152	89.3021	-21.2867	89.6515	-21.3408	89.2968						
0.0250	-21.0308	89.2678	-21.0071	89.5943	-21.0599	89.2681						
0.0315	-19.6423	89.2118	-19.6178	89.2806	-19.6787	89.1407						
0.0400	-18.8561	89.1182	-18.8282	89.1682	-18.8858	89.0029						
0.0500	-17.7738	88.9887	-17.7412	89.0386	-17.8027	88.9010						
0.0630	-16.8024	88.7961	-16.7780	88.6990	-16.8353	88.7963						
0.0800	-15.8387	88.5977	-15.8130	88.5501	-15.8759	88.5627						
0.1000	-14.8724	88.1191	-14.8447	88.1146	-14.9088	88.1166	0.0020	-0.0027	0.0018	-0.0024	0.0019	-0.0029
0.1250	-13.9674	87.7247	-13.9414	87.7263	-13.9984	87.7833	0.0019	-0.0032	0.0018	-0.0026	0.0019	-0.0032
0.1600	-12.8256	87.0988	-12.7998	87.0354	-12.8600	87.1002	0.0017	-0.0051	0.0015	-0.0042	0.0017	-0.0050
0.2000	-11.8716	86.3094	-11.8427	86.2768	-11.9096	86.2897	0.0016	-0.0055	0.0015	-0.0046	0.0016	-0.0059
0.2500	-10.9070	85.4165	-10.8795	85.3849	-10.9441	85.4360	0.0017	-0.0080	0.0015	-0.0064	0.0016	-0.0079
0.3150	-9.8986	84.2822	-9.8693	84.2497	-9.9339	84.3229	0.0016	-0.0123	0.0015	-0.0100	0.0016	-0.0124
0.4000	-8.8656	82.7734	-8.8396	82.7038	-8.9005	82.8168	0.0016	-0.0135	0.0015	-0.0108	0.0016	-0.0134
0.5000	-7.9270	81.0503	-7.9034	80.9865	-7.9623	81.1330	0.0015	-0.0142	0.0014	-0.0114	0.0015	-0.0142
0.6300	-6.9543	78.7942	-6.9307	78.7278	-6.9891	78.8951	0.0015	-0.0191	0.0013	-0.0155	0.0014	-0.0194
0.8000	-5.9602	75.8947	-5.9381	75.8141	-5.9941	76.0114	0.0014	-0.0266	0.0012	-0.0214	0.0014	-0.0268
1.0000	-5.0564	72.5690	-5.0344	72.4657	-5.0889	72.7231	0.0013	-0.0324	0.0012	-0.0270	0.0013	-0.0331
1.2500	-4.2052	68.6553	-4.1839	68.5465	-4.2359	68.8399	0.0013	-0.0406	0.0011	-0.0331	0.0013	-0.0414
1.6000	-3.3090	63.4761	-3.2888	63.3332	-3.3371	63.6914	0.0014	-0.0518	0.0013	-0.0422	0.0014	-0.0529
2.0000	-2.5701	58.0492	-2.5521	57.8958	-2.5943	58.2908	0.0016	-0.0651	0.0015	-0.0535	0.0016	-0.0672
2.5000	-1.9170	52.0991	-1.9017	51.9280	-1.9372	52.3571	0.0023	-0.0819	0.0021	-0.0669	0.0023	-0.0835
3.1500	-1.3435	45.5378	-1.3311	45.3583	-1.3592	45.7996	0.0035	-0.1022	0.0034	-0.0841	0.0035	-0.1050
4.0000	-0.8712	38.7123	-0.8620	38.5317	-0.8823	38.9660	0.0041	-0.1308	0.0040	-0.1073	0.0042	-0.1336
5.0000	-0.5404	32.6472	-0.5341	32.4755	-0.5477	32.8819	0.0029	-0.1632	0.0028	-0.1330	0.0029	-0.1667
6.3000	-0.2919	26.8945	-0.2882	26.7389	-0.2960	27.1031	0.0007	-0.2042	0.0006	-0.1676	0.0007	-0.2087
8.0000	-0.1131	21.6845	-0.1116	21.5503	-0.1145	21.8636	0.0003	-0.2614	0.0003	-0.2144	0.0003	-0.2672
10.0000	0.0000	17.5292	0.0000	17.4139	0.0000	17.6806	-0.0001	-0.3259	-0.0001	-0.2667	-0.0001	-0.3330
12.5000	0.0758	14.0249	0.0747	13.9291	0.0769	14.1533	0.0001	-0.4057	0.0002	-0.3325	0.0001	-0.4147
16.0000	0.1253	10.8153	0.1234	10.7393	0.1272	10.9226	-0.0046	-0.5178	-0.0044	-0.4235	-0.0046	-0.5291
20.0000	0.1534	8.4262	0.1510	8.3654	0.1557	8.5188	-0.0077	-0.6430	-0.0073	-0.5259	-0.0077	-0.6578
25.0000	0.1667	6.4290	0.1639	6.3826	0.1693	6.5114	-0.0145	-0.7995	-0.0139	-0.6533	-0.0145	-0.8177
31.5000	0.1717	4.6780	0.1687	4.6446	0.1746	4.7541	-0.0229	-0.9991	-0.0219	-0.8149	-0.0230	-1.0218
40.0000	-0.2899	3.1388	-0.2929	3.1161	-0.2868	3.2123	-0.4895	-1.2496	-0.4878	-1.0174	-0.4896	-1.2783

Digitizer #7

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.6488	89.6706	-24.3296	79.1498	-26.4277	114.5503						
0.0125	-23.3597	89.6556	-23.3857	87.1357	-23.3660	95.1741						
0.0160	-22.8111	89.4695	-22.7567	87.7168	-22.9639	94.2758						
0.0200	-21.2465	89.4199	-21.3771	88.8106	-21.3279	91.4913						
0.0250	-20.9773	89.4035	-21.0520	88.8897	-21.0479	91.2144						
0.0315	-19.6346	89.3684	-19.6101	88.8595	-19.6904	88.9736						
0.0400	-18.8330	89.1651	-18.8902	88.8595	-18.7932	88.8741						
0.0500	-17.7427	89.0473	-17.7778	88.8495	-17.7444	88.7597						
0.0630	-16.7743	88.7711	-16.7920	88.6815	-16.7770	88.4446						
0.0800	-15.8086	88.5751	-15.8492	88.6084	-15.8058	88.3313						
0.1000	-14.8391	88.0924	-14.8740	88.1399	-14.8420	88.0127	0.0181	-0.0137	0.0201	-0.0131	0.0119	-0.0133
0.1250	-13.9324	87.7452	-13.9811	87.5279	-13.9465	87.6698	0.0179	-0.0158	0.0199	-0.0158	0.0117	-0.0161
0.1600	-12.7945	87.0752	-12.8364	87.0743	-12.7958	87.0477	0.0179	-0.0240	0.0200	-0.0239	0.0118	-0.0241
0.2000	-11.8405	86.2889	-11.8704	86.3456	-11.8439	86.2551	0.0179	-0.0269	0.0200	-0.0271	0.0118	-0.0275
0.2500	-10.8722	85.4564	-10.9085	85.5185	-10.8759	85.3975	0.0179	-0.0357	0.0200	-0.0361	0.0118	-0.0362
0.3150	-9.8635	84.1987	-9.8987	84.2711	-9.8666	84.2162	0.0179	-0.0457	0.0200	-0.0460	0.0117	-0.0462
0.4000	-8.8338	82.6841	-8.8673	82.7611	-8.8361	82.6889	0.0179	-0.0569	0.0199	-0.0570	0.0117	-0.0570
0.5000	-7.8956	80.9454	-7.9293	81.0238	-7.8987	80.9380	0.0179	-0.0688	0.0199	-0.0695	0.0117	-0.0696
0.6300	-6.9233	78.6717	-6.9561	78.7665	-6.9259	78.6669	0.0178	-0.0928	0.0198	-0.0938	0.0115	-0.0935
0.8000	-5.9308	75.7283	-5.9626	75.8470	-5.9336	75.7174	0.0177	-0.1212	0.0198	-0.1222	0.0115	-0.1217
1.0000	-5.0268	72.3726	-5.0575	72.5078	-5.0298	72.3588	0.0177	-0.1439	0.0198	-0.1447	0.0115	-0.1449
1.2500	-4.1766	68.4205	-4.2057	68.5790	-4.1796	68.3991	0.0177	-0.1843	0.0197	-0.1850	0.0115	-0.1855
1.6000	-3.2824	63.1807	-3.3092	63.3682	-3.2856	63.1589	0.0177	-0.2352	0.0197	-0.2366	0.0115	-0.2378
2.0000	-2.5441	57.7136	-2.5683	57.9136	-2.5476	57.6839	0.0179	-0.2905	0.0200	-0.2921	0.0117	-0.2936
2.5000	-1.8935	51.6889	-1.9145	51.9048	-1.8973	51.6553	0.0186	-0.3638	0.0207	-0.3661	0.0124	-0.3675
3.1500	-1.3218	45.0588	-1.3391	45.2812	-1.3262	45.0193	0.0198	-0.4592	0.0218	-0.4619	0.0136	-0.4640
4.0000	-0.8524	38.1402	-0.8656	38.3565	-0.8573	38.0974	0.0204	-0.5855	0.0225	-0.5889	0.0142	-0.5917
5.0000	-0.5230	31.9754	-0.5328	32.1765	-0.5284	31.9304	0.0192	-0.7302	0.0213	-0.7345	0.0130	-0.7367
6.3000	-0.2759	26.0925	-0.2826	26.2703	-0.2817	26.0453	0.0170	-0.9162	0.0191	-0.9215	0.0108	-0.9247
8.0000	-0.0979	20.7066	-0.1021	20.8543	-0.1040	20.6563	0.0167	-1.1670	0.0187	-1.1737	0.0104	-1.1778
10.0000	0.0139	16.3397	0.0114	16.4587	0.0075	16.2851	0.0163	-1.4577	0.0183	-1.4663	0.0100	-1.4718
12.5000	0.0894	12.5626	0.0882	12.6538	0.0828	12.5014	0.0165	-1.8212	0.0185	-1.8317	0.0102	-1.8385
16.0000	0.1382	8.9808	0.1379	9.0408	0.1315	8.9108	0.0118	-2.3260	0.0138	-2.3395	0.0055	-2.3477
20.0000	0.1664	6.1531	0.1666	6.1864	0.1594	6.0703	0.0089	-2.9056	0.0108	-2.9222	0.0026	-2.9330
25.0000	0.1796	3.5978	0.1801	3.6053	0.1725	3.4992	0.0021	-3.6286	0.0040	-3.6502	-0.0043	-3.6633
31.5000	0.1848	1.1296	0.1854	1.1092	0.1774	1.0078	-0.0061	-4.5631	-0.0042	-4.5892	-0.0126	-4.6059
40.0000	-0.2771	-1.3602	-0.2766	-1.4091	-0.2849	-1.5109	-0.4727	-5.7777	-0.4710	-5.8114	-0.4794	-5.8322

Digitizer #8

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	0.0050	92.2969	-25.1128	87.3901	-25.4275	94.0208						
0.0125	0.0063	90.7268	-23.6541	87.8335	-23.5264	91.9006						
0.0160	0.0080	89.2016	-22.8311	88.9994	-22.8864	91.2058						
0.0200	0.0100	89.4669	-21.4026	89.1085	-21.2790	89.9267						
0.0250	0.0125	89.2016	-21.0744	88.9994	-21.0117	89.8955						
0.0315	0.0158	89.0720	-19.5940	88.9984	-19.5970	89.4791						
0.0400	0.0200	89.0173	-18.8210	88.9585	-18.8700	89.0822						
0.0500	0.0250	88.9129	-17.7468	88.9464	-17.7617	88.6052						
0.0630	0.0315	88.6095	-16.7869	88.7985	-16.7868	88.6542						
0.0800	0.0400	88.3891	-15.8189	88.5415	-15.8193	88.3221						
0.1000	0.0500	88.1647	-14.8557	88.1136	-14.8579	88.0635	0.0029	-0.0049	0.0026	-0.0035	0.0026	-0.0037
0.1250	0.0625	87.7276	-13.9541	87.7389	-13.9620	87.7366	0.0026	-0.0049	0.0023	-0.0035	0.0023	-0.0037
0.1600	0.0800	87.0763	-12.8162	87.0905	-12.8114	87.1475	0.0026	-0.0059	0.0023	-0.0045	0.0023	-0.0049
0.2000	0.1000	86.1456	-11.8439	86.2606	-11.8562	86.1415	0.0026	-0.0062	0.0023	-0.0046	0.0023	-0.0049
0.2500	0.1250	85.4525	-10.8783	85.3916	-10.8869	85.4549	0.0026	-0.0098	0.0023	-0.0076	0.0023	-0.0081
0.3150	0.1575	84.2963	-9.8829	84.2383	-9.8832	84.4241	0.0025	-0.0114	0.0023	-0.0090	0.0023	-0.0097
0.4000	0.2000	82.7208	-8.8517	82.7364	-8.8500	82.7659	0.0025	-0.0145	0.0022	-0.0109	0.0023	-0.0121
0.5000	0.2500	80.9929	-7.9123	81.0097	-7.9126	81.0904	0.0025	-0.0186	0.0022	-0.0147	0.0023	-0.0161
0.6300	0.3150	78.7399	-6.9426	78.7517	-6.9403	78.8499	0.0024	-0.0225	0.0021	-0.0178	0.0022	-0.0192
0.8000	0.4000	75.8516	-5.9485	75.8510	-5.9469	75.9811	0.0023	-0.0280	0.0020	-0.0218	0.0021	-0.0243
1.0000	0.5000	72.5075	-5.0448	72.5053	-5.0432	72.6693	0.0023	-0.0356	0.0020	-0.0281	0.0020	-0.0307
1.2500	0.6250	68.5984	-4.1934	68.5874	-4.1923	68.7902	0.0022	-0.0440	0.0020	-0.0349	0.0020	-0.0383
1.6000	0.8000	63.4021	-3.3000	63.3918	-3.2990	63.6351	0.0023	-0.0562	0.0020	-0.0451	0.0021	-0.0491
2.0000	1.0000	57.9811	-2.5594	57.9686	-2.5591	58.2440	0.0025	-0.0694	0.0023	-0.0558	0.0023	-0.0608
2.5000	1.2500	52.0087	-1.9079	51.9986	-1.9080	52.2966	0.0031	-0.0868	0.0029	-0.0706	0.0030	-0.0767
3.1500	1.5750	45.4508	-1.3358	45.4456	-1.3362	45.7516	0.0044	-0.1077	0.0042	-0.0872	0.0043	-0.0950
4.0000	2.0000	38.6225	-0.8658	38.6228	-0.8665	38.9202	0.0050	-0.1366	0.0048	-0.1113	0.0048	-0.1210
5.0000	2.5000	32.5529	-0.5360	32.5600	-0.5366	32.8332	0.0037	-0.1718	0.0036	-0.1399	0.0036	-0.1526
6.3000	3.1500	26.8063	-0.2895	26.8195	-0.2900	27.0581	0.0015	-0.2156	0.0014	-0.1761	0.0014	-0.1916
8.0000	4.0000	21.6130	-0.1109	21.6301	-0.1112	21.8288	0.0011	-0.2744	0.0010	-0.2242	0.0010	-0.2447
10.0000	5.0000	17.4648	0.0006	17.4859	0.0006	17.6463	0.0007	-0.3411	0.0006	-0.2786	0.0006	-0.3037
12.5000	6.2500	13.9697	0.0759	13.9946	0.0761	14.1189	0.0010	-0.4249	0.0010	-0.3475	0.0010	-0.3787
16.0000	8.0000	10.7768	0.1246	10.8050	0.1251	10.8943	-0.0039	-0.5421	-0.0038	-0.4433	-0.0038	-0.4832
20.0000	10.0000	8.3947	0.1525	8.4268	0.1531	8.4872	-0.0069	-0.6758	-0.0066	-0.5521	-0.0068	-0.6021
25.0000	12.5000	6.3999	0.1656	6.4370	0.1664	6.4721	-0.0138	-0.8396	-0.0132	-0.6850	-0.0135	-0.7479
31.5000	15.7500	4.6649	0.1706	4.7095	0.1715	4.7171	-0.0223	-1.0487	-0.0213	-0.8546	-0.0218	-0.9338
40.0000	20.0000	3.1348	-0.2916	3.1885	-0.2905	3.1702	-0.4894	-1.3137	-0.4877	-1.0690	-0.4884	-1.1682

Digitizer #9

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.6478	89.3457	-25.8615	104.6114	-25.3071	79.5894						
0.0125	-23.4241	91.4191	-23.4790	91.6390	-23.3552	88.9858						
0.0160	-22.7307	91.4191	-22.9673	91.6390	-22.7301	90.2870						
0.0200	-21.3164	89.6549	-21.3369	88.9621	-21.2412	89.7572						
0.0250	-21.0223	89.6348	-21.0222	88.7899	-20.9888	90.1102						
0.0315	-19.6187	89.0568	-19.7278	89.2972	-19.5473	89.1838						
0.0400	-18.8430	89.2300	-18.9108	89.0860	-18.7859	89.3882						
0.0500	-17.7610	88.9955	-17.8102	89.0318	-17.7082	89.0148						
0.0630	-16.7841	88.7011	-16.8150	88.9286	-16.7454	88.6038						
0.0800	-15.8256	88.5242	-15.8711	88.5150	-15.7756	88.5798						
0.1000	-14.8570	88.1239	-14.9037	88.0795	-14.8073	88.1127	0.0159	-0.0066	0.0178	-0.0070	0.0263	-0.0071
0.1250	-13.9519	87.6961	-14.0043	87.7246	-13.9017	87.6601	0.0160	-0.0064	0.0180	-0.0063	0.0264	-0.0063
0.1600	-12.8129	87.0400	-12.8630	87.0896	-12.7603	87.0074	0.0158	-0.0052	0.0177	-0.0049	0.0262	-0.0050
0.2000	-11.8582	86.2756	-11.9042	86.3626	-11.8072	86.1766	0.0157	-0.0052	0.0176	-0.0049	0.0262	-0.0050
0.2500	-10.8913	85.4171	-10.9409	85.5504	-10.8397	85.3906	0.0158	-0.0093	0.0177	-0.0098	0.0262	-0.0093
0.3150	-9.8844	84.2346	-9.9322	84.2861	-9.8307	84.1571	0.0159	-0.0120	0.0177	-0.0122	0.0262	-0.0119
0.4000	-8.8542	82.7458	-8.9037	82.8276	-8.8029	82.6513	0.0158	-0.0130	0.0177	-0.0134	0.0261	-0.0135
0.5000	-7.9159	81.0062	-7.9635	81.1080	-7.8657	80.8856	0.0158	-0.0160	0.0177	-0.0164	0.0261	-0.0161
0.6300	-6.9425	78.7490	-6.9899	78.8865	-6.8936	78.6005	0.0158	-0.0198	0.0177	-0.0203	0.0261	-0.0202
0.8000	-5.9500	75.8380	-5.9956	76.0138	-5.9023	75.6575	0.0157	-0.0270	0.0176	-0.0277	0.0261	-0.0276
1.0000	-5.0462	72.5171	-5.0902	72.7215	-5.0004	72.2985	0.0155	-0.0300	0.0174	-0.0308	0.0259	-0.0305
1.2500	-4.1958	68.6003	-4.2374	68.8424	-4.1526	68.3434	0.0155	-0.0385	0.0174	-0.0395	0.0258	-0.0392
1.6000	-3.3015	63.4094	-3.3398	63.6956	-3.2626	63.1099	0.0156	-0.0500	0.0175	-0.0512	0.0260	-0.0505
2.0000	-2.5611	58.0436	-2.5948	58.3642	-2.5265	57.7074	0.0159	-0.0625	0.0177	-0.0637	0.0262	-0.0632
2.5000	-1.9096	52.0222	-1.9383	52.3674	-1.8807	51.6639	0.0165	-0.0773	0.0184	-0.0793	0.0268	-0.0786
3.1500	-1.3373	45.4626	-1.3599	45.8186	-1.3149	45.0970	0.0178	-0.0977	0.0196	-0.0998	0.0281	-0.0984
4.0000	-0.8667	38.6333	-0.8831	38.9846	-0.8508	38.2810	0.0183	-0.1257	0.0202	-0.1284	0.0287	-0.1267
5.0000	-0.5369	32.5698	-0.5478	32.8989	-0.5263	32.2457	0.0172	-0.1567	0.0191	-0.1608	0.0275	-0.1591
6.3000	-0.2894	26.8259	-0.2957	27.1218	-0.2835	26.5414	0.0149	-0.1963	0.0168	-0.2000	0.0253	-0.1988
8.0000	-0.1113	21.6244	-0.1139	21.8799	-0.1090	21.3849	0.0145	-0.2496	0.0164	-0.2553	0.0249	-0.2526
10.0000	0.0004	17.4740	0.0004	17.6924	0.0004	17.2761	0.0142	-0.3120	0.0160	-0.3186	0.0245	-0.3152
12.5000	0.0759	13.9699	0.0777	14.1546	0.0742	13.8106	0.0144	-0.3883	0.0163	-0.3959	0.0247	-0.3917
16.0000	0.1249	10.7770	0.1280	10.9306	0.1221	10.6555	0.0097	-0.4931	0.0115	-0.5036	0.0200	-0.4986
20.0000	0.1528	8.3893	0.1567	8.5201	0.1493	8.2980	0.0067	-0.6139	0.0085	-0.6266	0.0170	-0.6206
25.0000	0.1660	6.3998	0.1705	6.5121	0.1621	6.3337	0.0000	-0.7627	0.0019	-0.7789	0.0103	-0.7714
31.5000	0.1691	4.6530	0.1740	4.7523	0.1650	4.6111	-0.0090	-0.9534	-0.0072	-0.9742	0.0013	-0.9639
40.0000	-0.2913	3.1151	-0.2862	3.2053	-0.2955	3.0954	-0.4748	-1.1947	-0.4730	-1.2205	-0.4646	-1.2081

Digitizer #10

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-26.1062	91.3466	-26.4427	128.9577	-25.2979	116.5633						
0.0125	-23.8655	88.1696	-24.2983	86.5148	-23.1898	87.5621						
0.0160	-22.2736	89.8624	-22.1685	90.0280	-22.2085	91.2593						
0.0200	-21.1186	89.5202	-21.0776	90.0280	-21.2116	89.6842						
0.0250	-20.8704	89.5193	-20.8312	90.0091	-21.0069	89.5500						
0.0315	-19.7176	89.5193	-19.7195	90.0091	-19.6857	89.5500						
0.0400	-18.8419	89.2998	-18.8114	89.4150	-18.9190	89.4195						
0.0500	-17.7589	89.1797	-17.7281	89.3483	-17.8273	88.6730						
0.0630	-16.8104	88.8580	-16.7845	88.9326	-16.8719	88.5275						
0.0800	-15.8551	88.5959	-15.8332	88.2129	-15.8782	88.2834						
0.1000	-14.8424	88.1067	-14.8363	88.0416	-14.9431	87.9703	0.0140	-0.0017	0.0142	-0.0016	0.0142	-0.0018
0.1250	-13.9263	87.6286	-13.9134	87.6564	-14.0249	87.7689	0.0137	-0.0018	0.0139	-0.0019	0.0139	-0.0020
0.1600	-12.8092	87.0614	-12.8100	86.9725	-12.8874	87.0414	0.0135	-0.0042	0.0138	-0.0041	0.0138	-0.0037
0.2000	-11.8374	86.4045	-11.8360	86.3410	-11.9307	86.2816	0.0135	-0.0042	0.0138	-0.0041	0.0138	-0.0037
0.2500	-10.9022	85.3632	-10.8924	85.3718	-10.9632	85.5623	0.0136	-0.0058	0.0138	-0.0064	0.0138	-0.0056
0.3150	-9.8734	84.2484	-9.8557	84.1827	-9.9449	84.3701	0.0135	-0.0103	0.0137	-0.0105	0.0137	-0.0100
0.4000	-8.8464	82.7711	-8.8389	82.7165	-8.9265	82.8774	0.0134	-0.0108	0.0136	-0.0116	0.0137	-0.0110
0.5000	-7.9059	81.0163	-7.9010	80.9883	-7.9846	81.2030	0.0133	-0.0136	0.0136	-0.0136	0.0136	-0.0138
0.6300	-6.9355	78.7765	-6.9261	78.7486	-7.0113	78.9666	0.0133	-0.0183	0.0136	-0.0192	0.0136	-0.0184
0.8000	-5.9390	75.8412	-5.9303	75.8171	-6.0137	76.0956	0.0133	-0.0287	0.0136	-0.0293	0.0136	-0.0285
1.0000	-5.0368	72.5339	-5.0291	72.4794	-5.1084	72.8295	0.0135	-0.0319	0.0137	-0.0334	0.0137	-0.0321
1.2500	-4.1859	68.6088	-4.1794	68.5470	-4.2553	68.9566	0.0134	-0.0394	0.0136	-0.0410	0.0136	-0.0395
1.6000	-3.2894	63.4009	-3.2833	63.3307	-3.3535	63.7941	0.0133	-0.0505	0.0136	-0.0525	0.0136	-0.0506
2.0000	-2.5491	58.0134	-2.5452	57.9301	-2.6075	58.4656	0.0137	-0.0613	0.0139	-0.0633	0.0140	-0.0611
2.5000	-1.8977	52.0592	-1.8956	51.9697	-1.9492	52.5454	0.0146	-0.0793	0.0148	-0.0822	0.0148	-0.0789
3.1500	-1.3249	45.5113	-1.3244	45.4239	-1.3680	46.0193	0.0156	-0.0986	0.0158	-0.1024	0.0158	-0.0984
4.0000	-0.8535	38.6660	-0.8545	38.5913	-0.8873	39.1722	0.0164	-0.1248	0.0167	-0.1293	0.0167	-0.1245
5.0000	-0.5226	32.6025	-0.5249	32.5365	-0.5485	33.0801	0.0151	-0.1535	0.0153	-0.1588	0.0153	-0.1530
6.3000	-0.2758	26.8699	-0.2789	26.8177	-0.2942	27.3004	0.0127	-0.1948	0.0129	-0.2020	0.0129	-0.1939
8.0000	-0.0963	21.6614	-0.1001	21.6233	-0.1093	22.0330	0.0123	-0.2439	0.0125	-0.2526	0.0126	-0.2429
10.0000	0.0153	17.4996	0.0112	17.4753	0.0062	17.8156	0.0120	-0.3102	0.0122	-0.3213	0.0122	-0.3092
12.5000	0.0915	13.9858	0.0872	13.9762	0.0853	14.2498	0.0123	-0.3880	0.0125	-0.4017	0.0125	-0.3868
16.0000	0.1402	10.7881	0.1359	10.7911	0.1362	10.9987	0.0074	-0.4907	0.0076	-0.5082	0.0076	-0.4898
20.0000	0.1681	8.3994	0.1638	8.4139	0.1653	8.5711	0.0045	-0.6129	0.0047	-0.6347	0.0048	-0.6110
25.0000	0.1818	6.4015	0.1776	6.4270	0.1800	6.5365	-0.0021	-0.7609	-0.0020	-0.7885	-0.0018	-0.7587
31.5000	0.1866	4.6530	0.1823	4.6938	0.1854	4.7592	-0.0103	-0.9517	-0.0103	-0.9864	-0.0100	-0.9489
40.0000	-0.2757	3.1115	-0.2797	3.1652	-0.2764	3.1879	-0.4767	-1.1903	-0.4767	-1.2346	-0.4763	-1.1865

Digitizer #11

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.5765	83.4782	-23.7951	80.5528	-24.5894	69.5384						
0.0125	-23.5703	83.4782	-23.6296	80.5528	-22.7788	83.7780						
0.0160	-23.2652	89.1965	-23.5501	87.2626	-22.5523	86.5097						
0.0200	-21.3464	89.1965	-21.3329	89.5077	-21.5317	89.3449						
0.0250	-21.2083	89.2139	-21.0541	89.6615	-21.1027	89.1416						
0.0315	-19.7640	89.1723	-19.7033	89.3262	-19.6549	89.3449						
0.0400	-18.8878	88.9352	-18.8893	88.9027	-18.8762	89.1416						
0.0500	-17.8120	88.9352	-17.7885	88.9027	-17.7165	88.9794						
0.0630	-16.9000	88.7205	-16.8417	88.6168	-16.8224	88.7513						
0.0800	-15.8786	88.6270	-15.8060	88.2136	-15.8469	88.4773						
0.1000	-14.9135	88.2004	-14.8646	88.0850	-14.8555	88.1854	0.0137	-0.0015	0.0137	-0.0015	0.0137	-0.0009
0.1250	-13.9922	87.8145	-13.9319	87.4199	-13.9148	87.6471	0.0135	-0.0029	0.0134	-0.0025	0.0135	-0.0032
0.1600	-12.8814	87.0779	-12.8237	87.1051	-12.8064	87.0411	0.0135	-0.0045	0.0134	-0.0041	0.0135	-0.0045
0.2000	-11.9167	86.4028	-11.8879	86.2883	-11.8377	86.3896	0.0134	-0.0045	0.0134	-0.0041	0.0134	-0.0045
0.2500	-10.9733	85.4017	-10.9138	85.5703	-10.8615	85.3135	0.0135	-0.0065	0.0134	-0.0062	0.0134	-0.0068
0.3150	-9.9394	84.2312	-9.8898	84.2826	-9.8589	84.2570	0.0134	-0.0102	0.0134	-0.0092	0.0134	-0.0103
0.4000	-8.9164	82.7566	-8.8623	82.6473	-8.8409	82.9078	0.0133	-0.0109	0.0132	-0.0099	0.0133	-0.0113
0.5000	-7.9804	81.1234	-7.9322	81.0673	-7.9041	80.9783	0.0133	-0.0136	0.0132	-0.0125	0.0133	-0.0138
0.6300	-7.0034	78.9845	-6.9515	78.8570	-6.9331	78.6936	0.0133	-0.0169	0.0132	-0.0159	0.0133	-0.0180
0.8000	-6.0059	76.0830	-5.9580	75.9424	-5.9373	75.9227	0.0133	-0.0283	0.0132	-0.0261	0.0132	-0.0285
1.0000	-5.0996	72.8385	-5.0513	72.5554	-5.0370	72.5225	0.0133	-0.0314	0.0133	-0.0288	0.0133	-0.0321
1.2500	-4.2464	68.9654	-4.2020	68.7057	-4.1870	68.5803	0.0133	-0.0384	0.0132	-0.0349	0.0133	-0.0394
1.6000	-3.3459	63.7843	-3.3018	63.4418	-3.2890	63.3922	0.0133	-0.0489	0.0132	-0.0454	0.0133	-0.0506
2.0000	-2.5983	58.4579	-2.5653	58.0834	-2.5499	57.9941	0.0136	-0.0596	0.0135	-0.0544	0.0136	-0.0610
2.5000	-1.9398	52.5366	-1.9117	52.1382	-1.8998	52.0302	0.0144	-0.0773	0.0144	-0.0705	0.0144	-0.0793
3.1500	-1.3583	45.9990	-1.3377	45.5958	-1.3278	45.4841	0.0155	-0.0965	0.0154	-0.0883	0.0155	-0.0993
4.0000	-0.8784	39.1448	-0.8646	38.7569	-0.8566	38.6546	0.0163	-0.1222	0.0162	-0.1118	0.0163	-0.1261
5.0000	-0.5406	33.0461	-0.5324	32.6917	-0.5262	32.5976	0.0150	-0.1504	0.0149	-0.1370	0.0149	-0.1546
6.3000	-0.2876	27.2666	-0.2844	26.9576	-0.2794	26.8731	0.0126	-0.1909	0.0126	-0.1734	0.0126	-0.1966
8.0000	-0.1035	22.0026	-0.1038	21.7412	-0.0997	21.6734	0.0122	-0.2381	0.0121	-0.2169	0.0121	-0.2456
10.0000	0.0113	17.7966	0.0084	17.5774	0.0118	17.5191	0.0119	-0.3028	0.0119	-0.2757	0.0118	-0.3119
12.5000	0.0898	14.2432	0.0852	14.0640	0.0882	14.0153	0.0122	-0.3789	0.0122	-0.3445	0.0122	-0.3893
16.0000	0.1401	11.0104	0.1344	10.8662	0.1370	10.8281	0.0073	-0.4797	0.0073	-0.4369	0.0072	-0.4932
20.0000	0.1691	8.5978	0.1626	8.4800	0.1651	8.4472	0.0044	-0.5986	0.0046	-0.5445	0.0043	-0.6158
25.0000	0.1834	6.5827	0.1765	6.4880	0.1790	6.4609	-0.0021	-0.7425	-0.0019	-0.6747	-0.0023	-0.7644
31.5000	0.1888	4.8291	0.1817	4.7523	0.1840	4.7283	-0.0103	-0.9289	-0.0098	-0.8447	-0.0106	-0.9568
40.0000	-0.2727	3.2860	-0.2801	3.2240	-0.2778	3.2052	-0.4766	-1.1618	-0.4758	-1.0544	-0.4770	-1.1960

Digitizer #12

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.0462	85.6486	-25.7895	91.4057	-26.0429	97.3730						
0.0125	-23.4394	89.4218	-23.4145	89.7454	-23.2279	91.8470						
0.0160	-22.8811	89.0587	-22.7926	89.9207	-22.7570	90.7467						
0.0200	-21.2931	89.2485	-21.2328	89.3046	-21.2983	89.7726						
0.0250	-20.9778	89.2485	-20.9838	89.3046	-21.0639	89.7336						
0.0315	-19.6249	89.0587	-19.6581	89.1264	-19.6678	89.5904						
0.0400	-18.8412	89.0017	-18.8758	89.0969	-18.8950	89.3814						
0.0500	-17.7518	88.8808	-17.7759	89.0248	-17.8124	89.0005						
0.0630	-16.7714	88.5719	-16.8065	88.8803	-16.8597	88.9511						
0.0800	-15.8270	88.4473	-15.8273	88.5109	-15.8706	88.5377						
0.1000	-14.8445	88.1227	-14.8697	88.0535	-14.9115	87.9381	0.0022	-0.0523	0.0022	-0.0526	0.0022	-0.0525
0.1250	-13.9372	87.6472	-13.9670	87.5797	-14.0157	87.4963	0.0019	-0.0643	0.0019	-0.0644	0.0020	-0.0644
0.1600	-12.8057	87.0319	-12.8256	86.9834	-12.8638	86.9676	0.0019	-0.0896	0.0019	-0.0899	0.0019	-0.0898
0.2000	-11.8441	86.0895	-11.8672	86.3556	-11.9062	86.3502	0.0019	-0.1002	0.0019	-0.1003	0.0019	-0.1001
0.2500	-10.8844	85.2791	-10.9050	85.4323	-10.9529	85.3950	0.0019	-0.1312	0.0019	-0.1311	0.0019	-0.1317
0.3150	-9.8767	84.0617	-9.8860	84.1925	-9.9355	84.1869	0.0018	-0.1670	0.0018	-0.1673	0.0018	-0.1674
0.4000	-8.8439	82.5094	-8.8639	82.5945	-8.9089	82.6535	0.0018	-0.2072	0.0018	-0.2076	0.0018	-0.2078
0.5000	-7.9061	80.7237	-7.9244	80.7956	-7.9672	80.8611	0.0018	-0.2561	0.0018	-0.2562	0.0018	-0.2565
0.6300	-6.9340	78.4225	-6.9517	78.4603	-6.9943	78.5716	0.0017	-0.3365	0.0016	-0.3366	0.0017	-0.3372
0.8000	-5.9406	75.4112	-5.9584	75.4904	-5.9999	75.6300	0.0016	-0.4260	0.0016	-0.4264	0.0016	-0.4266
1.0000	-5.0367	71.9737	-5.0540	72.0578	-5.0951	72.2334	0.0016	-0.5296	0.0015	-0.5299	0.0016	-0.5305
1.2500	-4.1868	67.9218	-4.2036	68.0147	-4.2425	68.2289	0.0015	-0.6601	0.0015	-0.6603	0.0015	-0.6615
1.6000	-3.2931	62.5529	-3.3082	62.6615	-3.3439	62.9222	0.0015	-0.8550	0.0015	-0.8553	0.0015	-0.8565
2.0000	-2.5538	56.9147	-2.5680	57.0429	-2.5999	57.3311	0.0018	-1.0587	0.0018	-1.0591	0.0018	-1.0612
2.5000	-1.9039	50.6984	-1.9161	50.8382	-1.9432	51.1545	0.0025	-1.3187	0.0025	-1.3194	0.0025	-1.3216
3.1500	-1.3328	43.8082	-1.3427	43.9566	-1.3639	44.2841	0.0037	-1.6655	0.0037	-1.6662	0.0037	-1.6692
4.0000	-0.8640	36.5677	-0.8713	36.7176	-0.8866	37.0403	0.0043	-2.1180	0.0043	-2.1189	0.0043	-2.1222
5.0000	-0.5352	30.0014	-0.5402	30.1470	-0.5504	30.4465	0.0031	-2.6459	0.0030	-2.6472	0.0031	-2.6516
6.3000	-0.2888	23.6212	-0.2917	23.7561	-0.2975	24.0236	0.0008	-3.3300	0.0008	-3.3315	0.0008	-3.3370
8.0000	-0.1118	17.5857	-0.1130	17.7083	-0.1154	17.9347	0.0005	-4.2318	0.0005	-4.2340	0.0005	-4.2408
10.0000	-0.0001	12.4363	0.0000	12.5472	0.0000	12.7362	0.0001	-5.2919	0.0001	-5.2942	0.0001	-5.3032
12.5000	0.0752	7.6979	0.0761	7.7985	0.0777	7.9523	0.0003	-6.6089	0.0003	-6.6121	0.0003	-6.6229
16.0000	0.1238	2.7625	0.1253	2.8540	0.1281	2.9740	-0.0043	-8.4514	-0.0044	-8.4554	-0.0044	-8.4692
20.0000	0.1515	-1.6128	0.1535	-1.5260	0.1570	-1.4327	-0.0073	-10.5611	-0.0073	-10.5660	-0.0074	-10.5837
25.0000	0.1645	-6.1009	0.1669	-6.0157	0.1707	-5.9450	-0.0140	-13.2042	-0.0140	-13.2101	-0.0142	-13.2321
31.5000	0.1693	-11.0799	0.1720	-10.9922	0.1761	-10.9413	-0.0223	-16.6259	-0.0223	-16.6337	-0.0225	-16.6612
40.0000	-0.2928	-16.8605	-0.2898	-16.7653	-0.2855	-16.7327	-0.4889	-21.0920	-0.4889	-21.1020	-0.4892	-21.1362

Note that for the test involving Digitizer #12, it was later determined that the shore-side equipment had lost GPS lock and the time-stamp has a constant offset that resulted in the observed phase response being shifted.

Digitizer #13

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.4622	90.2866	-24.8378	89.4650	-25.6400	87.8958						
0.0125	-23.6016	90.9715	-23.2286	88.8293	-23.5329	88.3243						
0.0160	-22.9876	90.2866	-22.7069	88.7395	-22.8744	88.6399						
0.0200	-21.3366	90.1158	-21.2636	88.8293	-21.3108	88.7070						
0.0250	-21.0793	89.4862	-20.9907	88.7395	-21.0320	88.6604						
0.0315	-19.6434	89.2977	-19.6513	88.8293	-19.7015	88.7743						
0.0400	-18.8735	89.0758	-18.8307	88.7395	-18.8584	88.7070						
0.0500	-17.7966	89.0357	-17.7649	88.7816	-17.8263	88.6982						
0.0630	-16.8267	88.6947	-16.7410	88.6913	-16.7814	88.6494						
0.0800	-15.8802	88.4321	-15.8031	88.5056	-15.8681	88.4922						
0.1000	-14.9077	88.0675	-14.8356	88.0668	-14.8949	88.1728	0.0173	-0.0040	0.0229	-0.0045	0.0145	-0.0041
0.1250	-14.0184	87.7530	-13.9290	87.6863	-13.9967	87.6308	0.0173	-0.0036	0.0229	-0.0043	0.0145	-0.0032
0.1600	-12.8565	87.0787	-12.8068	86.9902	-12.8636	87.0682	0.0173	-0.0046	0.0229	-0.0047	0.0145	-0.0044
0.2000	-11.9005	86.3267	-11.8400	86.3021	-11.8966	86.3843	0.0173	-0.0046	0.0229	-0.0052	0.0145	-0.0045
0.2500	-10.9431	85.5393	-10.8813	85.3451	-10.9465	85.4281	0.0173	-0.0071	0.0229	-0.0076	0.0145	-0.0067
0.3150	-9.9243	84.3049	-9.8742	84.2367	-9.9317	84.3109	0.0173	-0.0088	0.0229	-0.0102	0.0145	-0.0086
0.4000	-8.8941	82.8022	-8.8446	82.7257	-8.8999	82.8290	0.0172	-0.0121	0.0228	-0.0142	0.0144	-0.0120
0.5000	-7.9570	81.1011	-7.9059	81.0073	-7.9595	81.1301	0.0172	-0.0144	0.0228	-0.0165	0.0144	-0.0146
0.6300	-6.9828	78.8625	-6.9337	78.7343	-6.9866	78.8718	0.0171	-0.0186	0.0227	-0.0215	0.0143	-0.0185
0.8000	-5.9895	75.9884	-5.9408	75.8225	-5.9922	76.0123	0.0170	-0.0261	0.0226	-0.0302	0.0142	-0.0259
1.0000	-5.0841	72.6853	-5.0372	72.4815	-5.0864	72.7046	0.0169	-0.0292	0.0226	-0.0337	0.0142	-0.0295
1.2500	-4.2312	68.7987	-4.1864	68.5546	-4.2334	68.8228	0.0169	-0.0386	0.0225	-0.0445	0.0141	-0.0386
1.6000	-3.3342	63.6536	-3.2936	63.3578	-3.3359	63.6776	0.0169	-0.0464	0.0226	-0.0538	0.0142	-0.0462
2.0000	-2.5913	58.2496	-2.5550	57.9155	-2.5930	58.2702	0.0171	-0.0603	0.0228	-0.0698	0.0143	-0.0600
2.5000	-1.9353	52.3121	-1.9047	51.9483	-1.9367	52.3346	0.0178	-0.0754	0.0234	-0.0870	0.0150	-0.0749
3.1500	-1.3574	45.7679	-1.3333	45.3893	-1.3586	45.7900	0.0192	-0.0934	0.0248	-0.1081	0.0164	-0.0929
4.0000	-0.8816	38.9415	-0.8643	38.5729	-0.8826	38.9664	0.0198	-0.1197	0.0254	-0.1384	0.0170	-0.1188
5.0000	-0.5470	32.8547	-0.5354	32.5097	-0.5476	32.8800	0.0184	-0.1481	0.0240	-0.1722	0.0156	-0.1467
6.3000	-0.2954	27.0807	-0.2889	26.7746	-0.2958	27.1067	0.0163	-0.1861	0.0219	-0.2159	0.0135	-0.1849
8.0000	-0.1139	21.8435	-0.1114	21.5816	-0.1142	21.8705	0.0160	-0.2375	0.0216	-0.2756	0.0132	-0.2358
10.0000	0.0003	17.6601	0.0003	17.4397	0.0004	17.6876	0.0156	-0.2962	0.0211	-0.3436	0.0128	-0.2942
12.5000	0.0773	14.1272	0.0754	13.9459	0.0775	14.1565	0.0159	-0.3698	0.0213	-0.4293	0.0131	-0.3677
16.0000	0.1273	10.9101	0.1242	10.7655	0.1278	10.9416	0.0112	-0.4706	0.0166	-0.5461	0.0084	-0.4677
20.0000	0.1561	8.5047	0.1522	8.3877	0.1566	8.5390	0.0083	-0.5857	0.0136	-0.6802	0.0055	-0.5823
25.0000	0.1696	6.4916	0.1653	6.3981	0.1703	6.5309	0.0015	-0.7271	0.0066	-0.8447	-0.0012	-0.7225
31.5000	0.1750	4.7359	0.1703	4.6621	0.1759	4.7818	-0.0065	-0.9099	-0.0018	-1.0581	-0.0093	-0.9046
40.0000	-0.2869	3.1889	-0.2916	3.1320	-0.2857	3.2436	-0.4729	-1.1379	-0.4688	-1.3249	-0.4757	-1.1309

Digitizer #14

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-24.5156	91.5223	-24.5014	86.1007	-24.8259	85.7820						
0.0125	-23.6067	91.4886	-24.2479	89.3518	-24.1146	85.8996						
0.0160	-22.9437	90.3753	-23.3029	90.4909	-23.3476	89.4352						
0.0200	-21.2892	89.9982	-21.4088	89.3310	-21.4400	89.1231						
0.0250	-20.9633	89.6477	-21.1611	89.3310	-21.2170	89.1231						
0.0315	-19.6322	89.4622	-19.6107	89.1847	-19.6105	89.0083						
0.0400	-18.8621	89.2823	-18.8737	89.0511	-18.8921	88.9717						
0.0500	-17.8080	89.1794	-17.7727	89.0511	-17.7744	88.9717						
0.0630	-16.8457	88.9715	-16.7962	88.5718	-16.7868	88.4537						
0.0800	-15.8652	88.5618	-15.8486	88.3442	-15.8496	88.2997						
0.1000	-14.9022	88.1388	-14.8625	87.9944	-14.8569	88.0030	0.0028	-0.0074	0.0028	-0.0071	0.0028	-0.0069
0.1250	-13.9976	87.7595	-13.9690	87.6735	-13.9703	87.6575	0.0028	-0.0107	0.0028	-0.0106	0.0028	-0.0103
0.1600	-12.8552	87.0584	-12.8149	86.9637	-12.8124	86.9396	0.0027	-0.0110	0.0028	-0.0112	0.0027	-0.0108
0.2000	-11.8970	86.3285	-11.8629	86.2708	-11.8584	86.2565	0.0027	-0.0111	0.0027	-0.0114	0.0027	-0.0110
0.2500	-10.9348	85.5051	-10.8971	85.4271	-10.8891	85.4834	0.0026	-0.0169	0.0027	-0.0172	0.0026	-0.0168
0.3150	-9.9217	84.2933	-9.8888	84.2251	-9.8864	84.2079	0.0026	-0.0218	0.0026	-0.0226	0.0026	-0.0217
0.4000	-8.8933	82.8104	-8.8600	82.7455	-8.8576	82.7288	0.0026	-0.0285	0.0026	-0.0287	0.0026	-0.0278
0.5000	-7.9545	81.0903	-7.9221	80.9999	-7.9182	80.9863	0.0026	-0.0330	0.0026	-0.0339	0.0026	-0.0327
0.6300	-6.9812	78.8352	-6.9486	78.7473	-6.9453	78.7318	0.0024	-0.0450	0.0025	-0.0459	0.0024	-0.0445
0.8000	-5.9875	75.9591	-5.9555	75.8488	-5.9523	75.8332	0.0023	-0.0560	0.0024	-0.0575	0.0024	-0.0553
1.0000	-5.0827	72.6424	-5.0514	72.5194	-5.0486	72.4968	0.0023	-0.0691	0.0023	-0.0704	0.0023	-0.0679
1.2500	-4.2297	68.7486	-4.1993	68.5984	-4.1971	68.5753	0.0023	-0.0883	0.0023	-0.0896	0.0023	-0.0868
1.6000	-3.3320	63.5772	-3.3040	63.3928	-3.3017	63.3702	0.0023	-0.1148	0.0023	-0.1163	0.0023	-0.1130
2.0000	-2.5897	58.1735	-2.5638	57.9586	-2.5624	57.9354	0.0026	-0.1411	0.0026	-0.1433	0.0026	-0.1386
2.5000	-1.9341	52.2180	-1.9115	51.9758	-1.9103	51.9518	0.0032	-0.1757	0.0032	-0.1788	0.0032	-0.1727
3.1500	-1.3569	45.6450	-1.3385	45.3838	-1.3377	45.3621	0.0046	-0.2216	0.0046	-0.2246	0.0046	-0.2175
4.0000	-0.8811	38.7893	-0.8674	38.5203	-0.8669	38.5016	0.0051	-0.2813	0.0051	-0.2860	0.0051	-0.2769
5.0000	-0.5464	32.6720	-0.5370	32.4116	-0.5367	32.3952	0.0039	-0.3534	0.0039	-0.3595	0.0039	-0.3476
6.3000	-0.2953	26.8575	-0.2898	26.6149	-0.2897	26.6011	0.0015	-0.4422	0.0016	-0.4492	0.0015	-0.4346
8.0000	-0.1134	21.5660	-0.1112	21.3482	-0.1111	21.3366	0.0013	-0.5649	0.0013	-0.5742	0.0013	-0.5552
10.0000	0.0007	17.3148	0.0007	17.1209	0.0007	17.1107	0.0009	-0.7033	0.0009	-0.7140	0.0009	-0.6907
12.5000	0.0780	13.6940	0.0764	13.5233	0.0764	13.5140	0.0012	-0.8783	0.0012	-0.8919	0.0013	-0.8627
16.0000	0.1280	10.3499	0.1251	10.1984	0.1251	10.1907	-0.0036	-1.1190	-0.0036	-1.1364	-0.0034	-1.0998
20.0000	0.1568	7.8015	0.1531	7.6630	0.1531	7.6550	-0.0065	-1.3968	-0.0065	-1.4182	-0.0063	-1.3722
25.0000	0.1704	5.6224	0.1661	5.4907	0.1661	5.4832	-0.0133	-1.7420	-0.0134	-1.7686	-0.0131	-1.7115
31.5000	0.1761	3.6365	0.1714	3.5065	0.1713	3.4981	-0.0215	-2.1861	-0.0216	-2.2206	-0.0212	-2.1483
40.0000	-0.2854	1.7893	-0.2906	1.6539	-0.2907	1.6443	-0.4883	-2.7573	-0.4884	-2.8002	-0.4877	-2.7096

Digitizer #15

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.7444	89.3852	-24.7657	88.9203	-26.1371	90.0412						
0.0125	-23.5592	89.2274	-23.2479	89.5937	-23.7595	89.7158						
0.0160	-22.9457	89.2274	-22.7178	89.5085	-23.0744	89.2564						
0.0200	-21.2686	89.1827	-21.2665	89.1784	-21.2395	89.2564						
0.0250	-20.9853	89.1688	-21.0107	89.1445	-20.9431	89.3049						
0.0315	-19.6523	89.1659	-19.6053	89.0903	-19.6326	89.2007						
0.0400	-18.8651	89.0344	-18.8290	89.0080	-18.8505	89.1478						
0.0500	-17.7695	88.8728	-17.7341	89.0080	-17.7495	88.9950						
0.0630	-16.8025	88.7019	-16.7536	88.7879	-16.7771	88.7308						
0.0800	-15.8345	88.5045	-15.8089	88.4296	-15.8226	88.5716						
0.1000	-14.8681	88.0603	-14.8367	88.1196	-14.8565	88.0697	0.0023	-0.0081	0.0023	-0.0084	0.0022	-0.0083
0.1250	-13.9630	87.6941	-13.9331	87.6838	-13.9511	87.6895	0.0023	-0.0099	0.0023	-0.0097	0.0022	-0.0097
0.1600	-12.8226	87.0212	-12.7917	86.9854	-12.8105	86.9911	0.0022	-0.0102	0.0023	-0.0099	0.0022	-0.0099
0.2000	-11.8651	86.2474	-11.8361	86.2507	-11.8592	86.2412	0.0022	-0.0106	0.0022	-0.0102	0.0021	-0.0105
0.2500	-10.9015	85.4207	-10.8695	85.3776	-10.8898	85.4538	0.0022	-0.0159	0.0022	-0.0155	0.0021	-0.0153
0.3150	-9.8905	84.2513	-9.8612	84.1971	-9.8802	84.2209	0.0021	-0.0209	0.0022	-0.0206	0.0021	-0.0200
0.4000	-8.8629	82.7436	-8.8342	82.6748	-8.8531	82.7183	0.0021	-0.0279	0.0022	-0.0276	0.0020	-0.0268
0.5000	-7.9240	81.0089	-7.8953	80.9410	-7.9144	80.9831	0.0021	-0.0326	0.0022	-0.0318	0.0020	-0.0315
0.6300	-6.9503	78.7508	-6.9223	78.6606	-6.9405	78.7145	0.0019	-0.0439	0.0020	-0.0431	0.0019	-0.0421
0.8000	-5.9576	75.8514	-5.9301	75.7470	-5.9479	75.8246	0.0019	-0.0546	0.0020	-0.0536	0.0018	-0.0526
1.0000	-5.0537	72.5131	-5.0271	72.3956	-5.0442	72.4837	0.0019	-0.0665	0.0019	-0.0653	0.0018	-0.0642
1.2500	-4.2022	68.5938	-4.1767	68.4567	-4.1925	68.5597	0.0019	-0.0850	0.0019	-0.0832	0.0018	-0.0825
1.6000	-3.3069	63.3960	-3.2835	63.2297	-3.2976	63.3467	0.0018	-0.1105	0.0019	-0.1084	0.0018	-0.1070
2.0000	-2.5672	57.9704	-2.5458	57.7792	-2.5581	57.9086	0.0021	-0.1358	0.0022	-0.1329	0.0021	-0.1316
2.5000	-1.9148	51.9961	-1.8962	51.7854	-1.9067	51.9236	0.0028	-0.1692	0.0028	-0.1657	0.0027	-0.1637
3.1500	-1.3416	45.4166	-1.3265	45.1924	-1.3347	45.3319	0.0041	-0.2134	0.0042	-0.2093	0.0041	-0.2066
4.0000	-0.8700	38.5639	-0.8589	38.3355	-0.8646	38.4707	0.0047	-0.2714	0.0047	-0.2665	0.0046	-0.2625
5.0000	-0.5388	32.4631	-0.5311	32.2415	-0.5349	32.3668	0.0034	-0.3407	0.0035	-0.3346	0.0034	-0.3297
6.3000	-0.2908	26.6738	-0.2862	26.4670	-0.2884	26.5794	0.0011	-0.4264	0.0012	-0.4182	0.0011	-0.4125
8.0000	-0.1114	21.4092	-0.1096	21.2213	-0.1105	21.3193	0.0009	-0.5446	0.0010	-0.5347	0.0009	-0.5273
10.0000	0.0010	17.1862	0.0010	17.0175	0.0009	17.1023	0.0005	-0.6779	0.0006	-0.6652	0.0005	-0.6564
12.5000	0.0773	13.5909	0.0759	13.4386	0.0764	13.5127	0.0008	-0.8464	0.0008	-0.8306	0.0008	-0.8194
16.0000	0.1265	10.2722	0.1239	10.1338	0.1249	10.1989	-0.0039	-1.0792	-0.0038	-1.0590	-0.0039	-1.0442
20.0000	0.1548	7.7440	0.1516	7.6138	0.1528	7.6739	-0.0068	-1.3461	-0.0067	-1.3208	-0.0067	-1.3027
25.0000	0.1682	5.5779	0.1644	5.4504	0.1658	5.5074	-0.0136	-1.6794	-0.0134	-1.6474	-0.0134	-1.6254
31.5000	0.1738	3.6130	0.1695	3.4827	0.1711	3.5391	-0.0218	-2.1080	-0.0216	-2.0681	-0.0214	-2.0400
40.0000	-0.2878	1.7811	-0.2926	1.6417	-0.2909	1.7009	-0.4883	-2.6585	-0.4880	-2.6078	-0.4877	-2.5718

Digitizer #16

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-26.1294	87.7529	-25.5654	84.6410	-25.6637	80.8841						
0.0125	-23.8858	88.7930	-23.6821	89.0734	-23.5678	84.8869						
0.0160	-22.9525	89.0836	-22.8622	90.0214	-22.8234	88.5250						
0.0200	-21.2540	89.1470	-21.1732	89.4740	-21.2171	89.2116						
0.0250	-20.9580	89.1470	-20.9085	89.2712	-20.9413	89.2116						
0.0315	-19.5840	89.0906	-19.5771	89.1750	-19.5971	89.0667						
0.0400	-18.8316	88.9893	-18.8364	89.0733	-18.8475	88.9613						
0.0500	-17.7256	88.9893	-17.7362	88.8911	-17.7372	88.9613						
0.0630	-16.7520	88.6460	-16.7582	88.5739	-16.7613	88.5988						
0.0800	-15.7894	88.5492	-15.7892	88.4478	-15.7960	88.5088						
0.1000	-14.8251	88.0471	-14.8309	88.0711	-14.8337	88.0672	0.0018	-0.0187	0.0017	-0.0183	0.0018	-0.0184
0.1250	-13.9250	87.6563	-13.9344	87.6204	-13.9387	87.6686	0.0018	-0.0250	0.0017	-0.0246	0.0018	-0.0249
0.1600	-12.7812	87.0337	-12.7894	87.0100	-12.7921	87.0284	0.0018	-0.0327	0.0017	-0.0322	0.0018	-0.0329
0.2000	-11.8274	86.2458	-11.8354	86.2525	-11.8337	86.2687	0.0018	-0.0364	0.0017	-0.0359	0.0018	-0.0367
0.2500	-10.8608	85.4033	-10.8706	85.4006	-10.8702	85.4019	0.0018	-0.0476	0.0016	-0.0472	0.0017	-0.0481
0.3150	-9.8495	84.1807	-9.8611	84.1749	-9.8609	84.1861	0.0017	-0.0621	0.0016	-0.0610	0.0017	-0.0622
0.4000	-8.8211	82.6435	-8.8298	82.6686	-8.8318	82.6668	0.0017	-0.0781	0.0016	-0.0764	0.0017	-0.0776
0.5000	-7.8818	80.8866	-7.8911	80.9090	-7.8933	80.9158	0.0017	-0.0965	0.0015	-0.0946	0.0016	-0.0965
0.6300	-6.9092	78.6047	-6.9180	78.6287	-6.9195	78.6437	0.0016	-0.1226	0.0015	-0.1198	0.0016	-0.1223
0.8000	-5.9157	75.6376	-5.9240	75.6742	-5.9259	75.6815	0.0015	-0.1569	0.0014	-0.1535	0.0015	-0.1565
1.0000	-5.0131	72.2400	-5.0206	72.2830	-5.0222	72.2925	0.0015	-0.1954	0.0014	-0.1904	0.0015	-0.1944
1.2500	-4.1628	68.2524	-4.1698	68.3012	-4.1712	68.3144	0.0014	-0.2450	0.0013	-0.2397	0.0014	-0.2445
1.6000	-3.2718	62.9685	-3.2774	63.0189	-3.2786	63.0379	0.0014	-0.3176	0.0013	-0.3105	0.0014	-0.3168
2.0000	-2.5343	57.4329	-2.5389	57.4900	-2.5402	57.5062	0.0017	-0.3947	0.0016	-0.3864	0.0017	-0.3944
2.5000	-1.8863	51.3608	-1.8900	51.4180	-1.8910	51.4349	0.0024	-0.4898	0.0023	-0.4791	0.0024	-0.4892
3.1500	-1.3187	44.6820	-1.3214	44.7340	-1.3221	44.7526	0.0037	-0.6190	0.0036	-0.6054	0.0037	-0.6178
4.0000	-0.8534	37.7084	-0.8551	37.7518	-0.8556	37.7707	0.0043	-0.7892	0.0042	-0.7723	0.0043	-0.7879
5.0000	-0.5283	31.4945	-0.5293	31.5286	-0.5296	31.5487	0.0031	-0.9864	0.0030	-0.9652	0.0030	-0.9849
6.3000	-0.2849	25.5663	-0.2854	25.5895	-0.2856	25.6109	0.0008	-1.2385	0.0007	-1.2117	0.0008	-1.2360
8.0000	-0.1097	20.1191	-0.1098	20.1305	-0.1099	20.1527	0.0005	-1.5754	0.0005	-1.5408	0.0005	-1.5720
10.0000	0.0001	15.6822	0.0001	15.6831	0.0001	15.7078	0.0001	-1.9685	0.0000	-1.9254	0.0000	-1.9642
12.5000	0.0738	11.8079	0.0739	11.7974	0.0740	11.8260	0.0003	-2.4573	0.0003	-2.4032	0.0003	-2.4519
16.0000	0.1215	8.0667	0.1217	8.0444	0.1218	8.0777	-0.0044	-3.1427	-0.0043	-3.0742	-0.0044	-3.1367
20.0000	0.1489	5.0583	0.1490	5.0232	0.1493	5.0627	-0.0074	-3.9265	-0.0071	-3.8406	-0.0073	-3.9183
25.0000	0.1615	2.2713	0.1616	2.2220	0.1618	2.2699	-0.0143	-4.9072	-0.0139	-4.8004	-0.0143	-4.8980
31.5000	0.1664	-0.5097	0.1663	-0.5751	0.1667	-0.5163	-0.0226	-6.1715	-0.0219	-6.0371	-0.0225	-6.1596
40.0000	-0.2956	-3.4106	-0.2958	-3.4971	-0.2953	-3.4236	-0.4894	-7.8199	-0.4881	-7.6497	-0.4892	-7.8050

Digitizer #17

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.9126	90.8458	-25.4323	87.7966	-24.3920	85.9566						
0.0125	-23.2116	89.8369	-23.5466	89.7039	-23.1891	89.2543						
0.0160	-22.7200	89.2375	-22.8345	89.9973	-22.7045	89.2160						
0.0200	-21.1714	89.2143	-21.3184	89.9973	-21.2384	89.1858						
0.0250	-20.9286	89.2162	-21.0277	89.7039	-20.9720	88.8120						
0.0315	-19.5731	89.1381	-19.6342	88.9700	-19.5301	88.8120						
0.0400	-18.8022	88.8414	-18.7810	88.9573	-18.8185	88.9201						
0.0500	-17.7048	88.7693	-17.6992	88.9573	-17.7157	88.8120						
0.0630	-16.7274	88.5731	-16.7305	88.5847	-16.7318	88.7051						
0.0800	-15.7779	88.4445	-15.7764	88.2467	-15.7646	88.4515						
0.1000	-14.8080	88.1110	-14.7901	88.0873	-14.8162	87.9862	0.0020	-0.0134	0.0020	-0.0136	0.0020	-0.0131
0.1250	-13.8928	87.6164	-13.9155	87.3688	-13.9172	87.6712	0.0020	-0.0161	0.0020	-0.0160	0.0019	-0.0158
0.1600	-12.7686	86.9543	-12.7583	87.0318	-12.7629	86.9737	0.0020	-0.0224	0.0020	-0.0227	0.0019	-0.0222
0.2000	-11.8019	86.1720	-11.7986	86.2501	-11.8226	86.1194	0.0020	-0.0236	0.0020	-0.0235	0.0020	-0.0229
0.2500	-10.8428	85.3277	-10.8313	85.3349	-10.8454	85.3183	0.0020	-0.0305	0.0020	-0.0307	0.0019	-0.0300
0.3150	-9.8325	84.1248	-9.8309	84.1591	-9.8439	84.2269	0.0019	-0.0412	0.0020	-0.0414	0.0019	-0.0404
0.4000	-8.8011	82.6267	-8.8008	82.6028	-8.8119	82.6559	0.0019	-0.0489	0.0019	-0.0484	0.0019	-0.0473
0.5000	-7.8648	80.8742	-7.8642	80.8512	-7.8747	80.9206	0.0019	-0.0640	0.0019	-0.0643	0.0019	-0.0625
0.6300	-6.8910	78.5831	-6.8905	78.5712	-6.8994	78.6348	0.0018	-0.0812	0.0018	-0.0812	0.0018	-0.0793
0.8000	-5.8978	75.6265	-5.8979	75.6055	-5.9060	75.6779	0.0018	-0.1042	0.0018	-0.1037	0.0017	-0.1008
1.0000	-4.9951	72.2375	-4.9959	72.2244	-5.0036	72.2837	0.0017	-0.1277	0.0017	-0.1279	0.0017	-0.1250
1.2500	-4.1459	68.2422	-4.1466	68.2319	-4.1534	68.3061	0.0016	-0.1620	0.0016	-0.1624	0.0016	-0.1587
1.6000	-3.2547	62.9570	-3.2557	62.9518	-3.2614	63.0253	0.0017	-0.2073	0.0017	-0.2095	0.0016	-0.2046
2.0000	-2.5193	57.4486	-2.5198	57.4461	-2.5248	57.5220	0.0020	-0.2569	0.0020	-0.2586	0.0019	-0.2526
2.5000	-1.8732	51.3814	-1.8743	51.3837	-1.8781	51.4566	0.0026	-0.3238	0.0026	-0.3262	0.0026	-0.3186
3.1500	-1.3082	44.7371	-1.3091	44.7433	-1.3119	44.8147	0.0039	-0.4038	0.0039	-0.4074	0.0038	-0.3979
4.0000	-0.8460	37.8227	-0.8467	37.8326	-0.8486	37.8994	0.0045	-0.5141	0.0045	-0.5185	0.0044	-0.5062
5.0000	-0.5228	31.6849	-0.5233	31.6970	-0.5245	31.7586	0.0032	-0.6426	0.0032	-0.6473	0.0032	-0.6322
6.3000	-0.2816	25.8500	-0.2820	25.8632	-0.2827	25.9204	0.0010	-0.8099	0.0010	-0.8159	0.0009	-0.7970
8.0000	-0.1084	20.5370	-0.1086	20.5519	-0.1088	20.6054	0.0007	-1.0290	0.0007	-1.0368	0.0007	-1.0120
10.0000	0.0001	16.2423	0.0001	16.2583	0.0001	16.3104	0.0002	-1.2859	0.0003	-1.2955	0.0002	-1.2653
12.5000	0.0733	12.5389	0.0733	12.5566	0.0735	12.6091	0.0005	-1.6061	0.0005	-1.6183	0.0004	-1.5805
16.0000	0.1203	9.0564	0.1205	9.0761	0.1209	9.1314	-0.0042	-2.0488	-0.0042	-2.0643	-0.0042	-2.0158
20.0000	0.1472	6.3159	0.1474	6.3387	0.1479	6.3997	-0.0072	-2.5625	-0.0072	-2.5814	-0.0071	-2.5204
25.0000	0.1595	3.8686	0.1598	3.8954	0.1605	3.9652	-0.0140	-3.1981	-0.0142	-3.2228	-0.0139	-3.1471
31.5000	0.1641	1.5243	0.1645	1.5568	0.1653	1.6391	-0.0223	-4.0199	-0.0225	-4.0500	-0.0221	-3.9545
40.0000	-0.2988	-0.8158	-0.2985	-0.7761	-0.2973	-0.6766	-0.4890	-5.0895	-0.4894	-5.1278	-0.4887	-5.0071

Digitizer #18

	BHZ		BH2		BH1		SHZ		SH2		SH1	
Frequency (Hz)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)	Amplitude (dB)	Phase (deg)
0.0100	-25.0637	86.6681	-25.3981	93.6011	-24.7225	88.0827						
0.0125	-23.2590	86.6681	-23.3781	93.6011	-23.3608	90.5552						
0.0160	-22.7084	87.9584	-22.8870	90.9392	-22.8565	89.3546						
0.0200	-21.3304	88.8144	-21.2494	90.1888	-21.2560	88.8550						
0.0250	-21.0567	88.6663	-20.9182	89.9199	-21.0304	88.8594						
0.0315	-19.6627	88.8180	-19.6705	89.7017	-19.6075	88.7584						
0.0400	-18.8504	88.8516	-18.8958	89.5063	-18.8623	88.7584						
0.0500	-17.7663	88.8180	-17.8084	88.9538	-17.7523	88.7013						
0.0630	-16.8244	88.6753	-16.8084	88.6545	-16.7603	88.4780						
0.0800	-15.8499	88.5105	-15.8572	88.2751	-15.8206	88.2623						
0.1000	-14.8878	87.9995	-14.8876	88.1317	-14.8508	87.9968	0.0022	-0.0521	0.0022	-0.0530	0.0022	-0.0530
0.1250	-13.9842	87.7199	-13.9836	87.6687	-13.9391	87.4715	0.0019	-0.0642	0.0019	-0.0645	0.0019	-0.0646
0.1600	-12.8406	86.9283	-12.8523	87.0430	-12.8074	87.0360	0.0018	-0.0894	0.0018	-0.0901	0.0018	-0.0906
0.2000	-11.8793	86.3156	-11.8919	86.1262	-11.8363	86.1404	0.0018	-0.0997	0.0018	-0.1001	0.0018	-0.1007
0.2500	-10.9247	85.3178	-10.9201	85.4009	-10.8820	85.2452	0.0018	-0.1312	0.0018	-0.1316	0.0018	-0.1314
0.3150	-9.9012	84.0645	-9.9196	84.1195	-9.8830	84.1701	0.0018	-0.1673	0.0018	-0.1683	0.0018	-0.1683
0.4000	-8.8763	82.5679	-8.8885	82.5942	-8.8455	82.5352	0.0017	-0.2074	0.0018	-0.2091	0.0018	-0.2091
0.5000	-7.9375	80.7912	-7.9524	80.8437	-7.9075	80.7515	0.0017	-0.2561	0.0017	-0.2574	0.0017	-0.2572
0.6300	-6.9646	78.5006	-6.9773	78.5460	-6.9365	78.4325	0.0016	-0.3366	0.0016	-0.3389	0.0017	-0.3384
0.8000	-5.9705	75.5342	-5.9844	75.5671	-5.9442	75.4270	0.0016	-0.4257	0.0016	-0.4289	0.0016	-0.4281
1.0000	-5.0661	72.1065	-5.0791	72.1643	-5.0402	71.9910	0.0015	-0.5296	0.0015	-0.5329	0.0015	-0.5321
1.2500	-4.2147	68.0775	-4.2271	68.1544	-4.1903	67.9436	0.0015	-0.6603	0.0014	-0.6643	0.0015	-0.6635
1.6000	-3.3187	62.7433	-3.3297	62.8252	-3.2957	62.5785	0.0015	-0.8561	0.0015	-0.8604	0.0015	-0.8598
2.0000	-2.5766	57.1270	-2.5863	57.2293	-2.5566	56.9486	0.0018	-1.0602	0.0018	-1.0656	0.0018	-1.0651
2.5000	-1.9233	50.9299	-1.9313	51.0371	-1.9063	50.7358	0.0024	-1.3205	0.0024	-1.3277	0.0024	-1.3271
3.1500	-1.3481	44.0500	-1.3542	44.1592	-1.3345	43.8483	0.0037	-1.6681	0.0037	-1.6768	0.0037	-1.6762
4.0000	-0.8751	36.8071	-0.8793	36.9135	-0.8652	36.6091	0.0043	-2.1210	0.0043	-2.1317	0.0043	-2.1308
5.0000	-0.5425	30.2266	-0.5453	30.3264	-0.5359	30.0434	0.0030	-2.6497	0.0030	-2.6648	0.0030	-2.6623
6.3000	-0.2929	23.8239	-0.2945	23.9151	-0.2891	23.6633	0.0008	-3.3345	0.0008	-3.3525	0.0008	-3.3503
8.0000	-0.1133	17.7630	-0.1140	17.8437	-0.1119	17.6296	0.0005	-4.2378	0.0004	-4.2614	0.0005	-4.2587
10.0000	0.0000	12.5901	0.0000	12.6637	0.0001	12.4845	0.0000	-5.3001	0.0000	-5.3285	0.0000	-5.3253
12.5000	0.0764	7.8313	0.0769	7.8991	0.0754	7.7513	0.0003	-6.6191	0.0002	-6.6544	0.0002	-6.6505
16.0000	0.1259	2.8767	0.1267	2.9415	0.1241	2.8249	-0.0044	-8.4631	-0.0045	-8.5083	-0.0045	-8.5038
20.0000	0.1542	-1.5113	0.1552	-1.4455	0.1519	-1.5392	-0.0074	-10.5768	-0.0077	-10.6333	-0.0076	-10.6273
25.0000	0.1676	-6.0079	0.1688	-5.9396	0.1651	-6.0126	-0.0142	-13.2232	-0.0144	-13.2928	-0.0145	-13.2858
31.5000	0.1727	-10.9904	0.1741	-10.9153	0.1702	-10.9719	-0.0225	-16.6495	-0.0229	-16.7378	-0.0230	-16.7292
40.0000	-0.2891	-16.7704	-0.2874	-16.6840	-0.2915	-16.7253	-0.4892	-21.1214	-0.4898	-21.2329	-0.4899	-21.2218

APPENDIX B: SELF-NOISE

Digitizer self-noise values are reported in units of dB relative to 1 V^2/Hz at the defined octave-band frequencies. The 90% uncertainty of the provided estimates are +/- 0.52454 dB for the broad-band channels and +/- 0.26183 dB for the short-period channels.

Digitizer #1

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-116.69	-123.32	-116.65			
0.0125	-117.92	-124.01	-117.55			
0.0160	-118.87	-125.00	-119.13			
0.0200	-120.71	-126.38	-120.84			
0.0250	-121.05	-127.32	-121.25			
0.0315	-122.58	-128.41	-123.22			
0.0400	-124.13	-130.28	-124.63			
0.0500	-126.58	-131.85	-126.98			
0.0630	-128.11	-133.58	-129.14			
0.0800	-129.96	-134.69	-131.26			
0.1000	-132.07	-135.35	-132.52	-132.66	-140.79	-137.62
0.1250	-133.11	-136.38	-133.93	-133.67	-141.79	-139.20
0.1600	-134.31	-137.11	-135.24	-134.57	-142.59	-140.77
0.2000	-135.89	-137.83	-136.48	-135.29	-143.62	-142.04
0.2500	-136.87	-138.02	-137.38	-136.22	-144.00	-143.38
0.3150	-137.83	-138.44	-137.78	-137.17	-144.48	-143.76
0.4000	-138.48	-138.76	-138.09	-137.80	-144.81	-144.21
0.5000	-138.60	-138.66	-138.29	-138.26	-144.91	-144.55
0.6300	-138.91	-138.65	-138.75	-139.00	-145.01	-144.78
0.8000	-139.37	-139.22	-138.94	-139.53	-145.18	-144.86
1.0000	-138.74	-138.97	-138.41	-139.88	-145.03	-144.72
1.2500	-139.58	-139.65	-139.21	-140.16	-145.28	-145.14
1.6000	-140.23	-139.63	-139.74	-140.52	-145.19	-145.15
2.0000	-140.10	-139.85	-139.68	-140.70	-145.22	-145.17
2.5000	-140.72	-140.60	-140.39	-140.97	-145.25	-145.18
3.1500	-141.37	-141.09	-141.22	-141.07	-145.33	-145.27
4.0000	-141.88	-141.81	-141.78	-141.36	-145.31	-145.23
5.0000	-142.51	-142.18	-142.44	-141.58	-145.38	-145.27
6.3000	-143.38	-143.08	-142.91	-141.83	-145.37	-145.32
8.0000	-143.98	-143.69	-143.79	-142.14	-145.35	-145.31
10.0000	-144.30	-144.06	-144.30	-142.44	-145.38	-145.37
12.5000	-144.68	-144.53	-144.47	-142.81	-145.35	-145.31
16.0000	-144.94	-144.70	-144.73	-143.25	-145.36	-145.35
20.0000	-144.97	-145.01	-145.14	-143.55	-145.39	-145.13
25.0000	-145.24	-145.31	-145.09	-143.96	-145.42	-145.38
31.5000	-145.29	-145.29	-145.23	-144.28	-145.42	-145.38
40.0000	-146.21	-146.07	-146.28	-145.46	-146.31	-146.33

Digitizer #2

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-117.38	-116.89	-114.09			
0.0125	-119.10	-117.43	-114.80			
0.0160	-119.10	-117.55	-114.85			
0.0200	-119.89	-117.70	-115.07			
0.0250	-120.15	-117.90	-115.12			
0.0315	-120.73	-119.57	-115.34			
0.0400	-121.14	-120.34	-117.01			
0.0500	-123.37	-123.34	-118.88			
0.0630	-124.68	-124.92	-120.32			
0.0800	-125.91	-126.64	-121.97			
0.1000	-128.93	-128.44	-124.14	-129.96	-132.29	-134.16
0.1250	-129.82	-131.19	-126.45	-131.80	-133.44	-135.31
0.1600	-132.33	-132.55	-129.06	-135.32	-133.55	-137.36
0.2000	-133.79	-135.10	-131.38	-138.06	-133.60	-139.25
0.2500	-135.35	-136.09	-133.21	-139.60	-133.80	-139.90
0.3150	-136.92	-137.79	-135.10	-141.59	-133.48	-140.25
0.4000	-137.66	-138.41	-136.49	-142.44	-133.10	-140.51
0.5000	-138.31	-139.43	-138.19	-143.05	-132.75	-140.44
0.6300	-138.59	-139.61	-138.83	-143.65	-133.30	-140.79
0.8000	-138.98	-139.87	-139.15	-143.90	-135.25	-141.69
1.0000	-139.02	-139.83	-139.39	-144.27	-136.38	-142.62
1.2500	-139.15	-140.04	-139.54	-144.43	-137.17	-142.71
1.6000	-139.62	-140.48	-139.89	-144.30	-138.36	-143.36
2.0000	-140.04	-140.98	-140.24	-144.53	-139.48	-143.74
2.5000	-140.66	-141.20	-141.02	-144.73	-141.15	-144.22
3.1500	-140.97	-141.78	-141.33	-144.76	-142.39	-144.30
4.0000	-141.52	-142.12	-141.96	-144.91	-143.81	-144.86
5.0000	-142.49	-143.14	-142.89	-144.91	-144.10	-144.87
6.3000	-143.33	-143.70	-143.45	-144.85	-144.49	-144.45
8.0000	-143.93	-144.13	-144.13	-144.78	-144.82	-144.77
10.0000	-144.28	-144.89	-144.56	-144.71	-144.96	-145.10
12.5000	-144.77	-144.63	-144.99	-144.98	-145.05	-144.94
16.0000	-144.77	-145.14	-145.20	-144.79	-145.24	-144.47
20.0000	-145.09	-145.29	-145.47	-144.92	-145.24	-144.70
25.0000	-145.29	-145.43	-145.40	-145.04	-145.19	-145.05
31.5000	-145.47	-145.19	-145.89	-145.30	-145.43	-145.13
40.0000	-146.27	-146.66	-146.58	-146.12	-146.59	-145.92

Digitizer #3

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-118.06	-123.87	-122.92			
0.0125	-118.52	-125.02	-124.09			
0.0160	-120.15	-126.93	-125.87			
0.0200	-121.59	-128.16	-127.48			
0.0250	-123.10	-128.90	-127.92			
0.0315	-123.88	-130.65	-128.95			
0.0400	-124.62	-131.08	-129.99			
0.0500	-125.20	-131.67	-130.71			
0.0630	-126.64	-132.93	-131.80			
0.0800	-127.56	-133.64	-132.56			
0.1000	-129.51	-134.84	-134.15	-139.72	-139.49	-134.17
0.1250	-130.36	-135.63	-134.59	-140.47	-140.16	-134.88
0.1600	-131.92	-136.08	-135.70	-141.60	-140.60	-136.60
0.2000	-133.37	-136.77	-136.43	-142.47	-141.47	-138.01
0.2500	-134.28	-137.35	-136.85	-143.21	-142.04	-139.06
0.3150	-135.54	-137.62	-137.66	-143.88	-142.62	-140.59
0.4000	-136.55	-138.22	-138.36	-144.28	-142.82	-141.64
0.5000	-137.69	-138.60	-138.64	-144.62	-143.28	-142.80
0.6300	-137.92	-138.72	-138.74	-144.73	-143.46	-143.20
0.8000	-138.88	-139.24	-139.25	-145.07	-143.65	-144.30
1.0000	-139.36	-139.48	-139.59	-145.11	-143.72	-144.96
1.2500	-139.77	-139.52	-139.94	-145.27	-143.87	-145.03
1.6000	-140.10	-139.75	-140.41	-145.37	-143.97	-145.15
2.0000	-140.59	-139.95	-140.38	-145.35	-144.04	-145.21
2.5000	-140.99	-140.58	-141.15	-145.33	-143.99	-145.30
3.1500	-141.66	-141.09	-141.68	-145.33	-144.08	-145.34
4.0000	-142.06	-142.08	-142.22	-145.22	-144.24	-145.28
5.0000	-142.87	-142.53	-142.92	-145.28	-144.48	-145.30
6.3000	-143.65	-143.32	-143.53	-145.35	-144.71	-145.31
8.0000	-144.27	-143.67	-144.31	-145.33	-144.70	-145.26
10.0000	-144.58	-144.48	-144.70	-145.30	-144.98	-145.33
12.5000	-144.98	-144.90	-144.88	-145.38	-145.15	-145.30
16.0000	-145.18	-145.24	-145.30	-145.30	-145.10	-145.46
20.0000	-145.43	-145.13	-145.27	-145.26	-145.11	-145.18
25.0000	-145.45	-145.44	-145.45	-145.35	-145.20	-145.25
31.5000	-145.45	-145.54	-145.49	-145.53	-145.41	-145.31
40.0000	-146.50	-146.36	-146.56	-146.19	-146.26	-146.24

Digitizer #4

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-121.23	-119.12	-112.92			
0.0125	-123.71	-121.38	-114.78			
0.0160	-124.87	-122.77	-116.45			
0.0200	-126.72	-124.93	-118.46			
0.0250	-126.96	-125.70	-119.28			
0.0315	-128.20	-126.30	-120.19			
0.0400	-130.02	-127.97	-121.59			
0.0500	-130.86	-128.42	-122.27			
0.0630	-131.75	-130.47	-124.09			
0.0800	-133.28	-130.99	-124.50			
0.1000	-134.53	-131.83	-125.95	-138.18	-138.08	-139.14
0.1250	-135.82	-133.20	-126.98	-139.22	-139.53	-139.84
0.1600	-136.63	-134.64	-129.12	-140.82	-140.30	-141.22
0.2000	-137.35	-135.76	-130.57	-141.41	-141.61	-142.29
0.2500	-137.88	-136.54	-132.07	-142.40	-142.52	-142.91
0.3150	-138.52	-137.46	-133.67	-143.39	-143.45	-143.60
0.4000	-138.94	-138.10	-134.93	-144.12	-143.93	-144.14
0.5000	-139.06	-138.55	-136.00	-144.36	-144.06	-144.30
0.6300	-138.93	-138.58	-136.15	-144.69	-144.31	-144.42
0.8000	-139.46	-139.23	-137.71	-144.92	-144.64	-144.66
1.0000	-139.69	-139.44	-138.24	-145.11	-144.74	-144.85
1.2500	-139.89	-139.66	-138.69	-145.15	-144.86	-144.91
1.6000	-140.07	-139.82	-139.30	-145.22	-144.85	-144.95
2.0000	-140.36	-140.20	-139.52	-145.27	-144.84	-145.01
2.5000	-141.09	-140.70	-140.13	-145.25	-144.86	-144.99
3.1500	-141.52	-141.21	-140.73	-145.32	-144.90	-145.02
4.0000	-142.06	-142.06	-141.31	-145.25	-145.00	-145.02
5.0000	-142.74	-142.59	-142.15	-145.26	-144.90	-145.12
6.3000	-143.53	-143.09	-142.99	-145.32	-144.92	-145.11
8.0000	-144.00	-143.81	-143.69	-145.26	-144.90	-145.05
10.0000	-144.53	-144.01	-144.10	-145.38	-145.04	-145.10
12.5000	-144.69	-144.58	-144.36	-145.31	-144.96	-145.11
16.0000	-145.11	-144.96	-144.83	-145.41	-144.99	-145.09
20.0000	-145.13	-144.99	-145.09	-145.25	-144.95	-144.96
25.0000	-145.30	-145.16	-145.10	-145.35	-145.01	-145.14
31.5000	-145.31	-145.39	-145.26	-145.35	-145.06	-145.08
40.0000	-146.37	-146.23	-146.32	-146.40	-145.93	-146.04

Digitizer #5

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-127.80	-126.74	-123.95			
0.0125	-127.80	-126.74	-123.95			
0.0160	-128.28	-127.06	-124.26			
0.0200	-128.28	-127.06	-124.26			
0.0250	-128.20	-127.41	-124.53			
0.0315	-128.20	-127.33	-124.42			
0.0400	-128.66	-127.42	-124.56			
0.0500	-128.91	-127.41	-124.52			
0.0630	-128.77	-127.35	-124.33			
0.0800	-129.31	-127.79	-124.72			
0.1000	-129.53	-128.14	-124.50	-131.11	-132.66	-132.92
0.1250	-128.95	-127.61	-124.56	-131.31	-133.19	-132.84
0.1600	-129.12	-127.56	-124.67	-131.40	-133.12	-133.07
0.2000	-129.17	-127.65	-124.74	-131.72	-133.65	-133.19
0.2500	-129.32	-127.69	-125.08	-131.69	-133.33	-133.48
0.3150	-129.38	-127.88	-125.36	-131.99	-133.68	-133.58
0.4000	-129.66	-128.25	-125.68	-132.04	-133.77	-133.60
0.5000	-129.69	-128.13	-125.61	-132.17	-133.76	-133.81
0.6300	-129.91	-128.37	-125.68	-132.36	-134.20	-134.12
0.8000	-130.10	-128.74	-125.98	-132.79	-134.23	-134.26
1.0000	-130.64	-129.33	-126.55	-133.34	-134.48	-134.73
1.2500	-131.44	-129.82	-126.99	-134.25	-135.23	-135.54
1.6000	-132.42	-130.99	-127.96	-135.36	-136.62	-136.98
2.0000	-133.42	-132.01	-129.14	-136.33	-137.90	-138.16
2.5000	-135.31	-133.90	-131.06	-138.17	-139.78	-139.93
3.1500	-137.26	-136.14	-133.59	-139.99	-141.29	-141.59
4.0000	-139.72	-138.85	-136.89	-141.66	-143.03	-143.06
5.0000	-141.79	-141.43	-140.38	-143.54	-144.22	-144.19
6.3000	-143.06	-143.29	-142.68	-144.77	-144.82	-144.70
8.0000	-143.83	-143.87	-143.80	-145.20	-145.25	-144.82
10.0000	-144.25	-144.46	-144.36	-145.20	-145.20	-144.62
12.5000	-144.72	-144.76	-144.62	-145.25	-145.19	-144.93
16.0000	-144.85	-144.93	-144.90	-145.18	-145.37	-144.94
20.0000	-145.05	-145.11	-145.04	-145.18	-145.30	-144.74
25.0000	-145.23	-145.26	-145.16	-145.28	-145.36	-145.03
31.5000	-145.32	-145.28	-145.25	-145.20	-145.35	-144.92
40.0000	-146.31	-146.29	-146.32	-146.26	-146.33	-145.92

Digitizer #6

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-118.32	-111.29	-113.46			
0.0125	-120.41	-113.50	-115.21			
0.0160	-122.08	-113.82	-116.86			
0.0200	-123.64	-115.12	-118.81			
0.0250	-124.26	-115.81	-119.52			
0.0315	-124.69	-115.83	-119.96			
0.0400	-126.23	-117.22	-120.99			
0.0500	-126.51	-117.61	-121.34			
0.0630	-126.63	-118.83	-122.05			
0.0800	-127.54	-120.20	-122.78			
0.1000	-128.24	-120.93	-123.54	-126.25	-128.13	-128.53
0.1250	-129.44	-122.58	-124.96	-126.88	-129.32	-129.36
0.1600	-131.35	-123.89	-127.05	-128.64	-130.14	-131.19
0.2000	-132.45	-125.07	-128.09	-129.41	-131.03	-132.30
0.2500	-133.10	-126.12	-129.01	-130.31	-131.25	-133.10
0.3150	-133.60	-126.85	-129.74	-131.50	-131.63	-134.08
0.4000	-134.55	-128.27	-130.97	-132.56	-131.92	-135.62
0.5000	-135.76	-130.01	-132.67	-133.75	-132.29	-137.22
0.6300	-135.87	-131.24	-133.17	-134.70	-132.59	-138.08
0.8000	-137.59	-134.06	-135.71	-136.42	-133.00	-140.48
1.0000	-138.24	-135.75	-137.33	-137.70	-133.46	-142.02
1.2500	-139.04	-137.67	-138.72	-138.83	-134.09	-143.31
1.6000	-139.40	-139.27	-139.77	-140.28	-134.92	-144.19
2.0000	-139.76	-140.21	-140.38	-141.27	-135.75	-144.56
2.5000	-140.58	-141.04	-141.03	-142.14	-136.89	-144.77
3.1500	-140.99	-141.71	-141.75	-142.80	-138.08	-145.04
4.0000	-141.66	-142.32	-142.27	-143.26	-139.23	-145.04
5.0000	-142.52	-143.05	-142.68	-143.75	-140.56	-145.13
6.3000	-143.38	-143.65	-143.47	-144.01	-141.59	-145.09
8.0000	-143.84	-143.89	-144.24	-144.38	-142.60	-145.16
10.0000	-144.30	-144.59	-144.42	-144.51	-143.32	-145.19
12.5000	-144.67	-144.98	-144.72	-144.72	-143.92	-145.13
16.0000	-145.06	-145.13	-144.97	-144.82	-144.32	-145.16
20.0000	-145.14	-145.22	-145.34	-144.79	-144.70	-145.12
25.0000	-145.29	-145.15	-145.33	-144.95	-144.76	-145.19
31.5000	-145.36	-145.21	-145.57	-145.06	-145.10	-145.21
40.0000	-146.31	-146.49	-146.35	-146.13	-146.15	-146.25

Digitizer #7

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-112.03	-113.96	-110.86			
0.0125	-112.59	-114.62	-112.03			
0.0160	-113.41	-114.97	-112.96			
0.0200	-114.91	-116.85	-114.38			
0.0250	-115.20	-117.25	-114.40			
0.0315	-115.94	-117.76	-114.87			
0.0400	-118.68	-118.21	-116.89			
0.0500	-119.73	-118.55	-117.42			
0.0630	-122.64	-118.93	-117.92			
0.0800	-123.43	-119.54	-118.51			
0.1000	-125.09	-121.18	-119.77	-129.51	-128.83	-123.23
0.1250	-126.44	-123.01	-122.64	-132.18	-130.71	-125.98
0.1600	-128.39	-124.63	-123.58	-133.56	-131.75	-127.77
0.2000	-129.37	-126.60	-125.29	-135.24	-133.73	-130.08
0.2500	-131.13	-129.19	-127.39	-136.79	-135.36	-132.86
0.3150	-132.88	-131.41	-129.69	-139.07	-137.87	-135.57
0.4000	-135.85	-134.04	-132.20	-141.75	-139.76	-139.19
0.5000	-136.97	-135.97	-133.89	-142.65	-140.83	-140.82
0.6300	-137.90	-137.06	-135.23	-143.29	-141.50	-142.33
0.8000	-138.60	-138.09	-136.79	-144.06	-142.06	-143.35
1.0000	-138.94	-138.63	-137.44	-144.33	-142.54	-143.90
1.2500	-139.33	-139.16	-137.83	-144.37	-143.23	-144.20
1.6000	-139.63	-139.43	-138.38	-144.48	-143.57	-144.29
2.0000	-139.89	-139.42	-138.89	-144.58	-143.89	-144.41
2.5000	-140.30	-140.30	-139.66	-144.66	-144.14	-144.52
3.1500	-140.92	-140.85	-140.18	-144.80	-144.42	-144.55
4.0000	-141.57	-141.61	-141.13	-144.75	-144.59	-144.52
5.0000	-142.68	-142.01	-142.07	-144.85	-144.75	-144.56
6.3000	-143.06	-143.08	-142.62	-144.86	-144.78	-144.62
8.0000	-143.63	-143.45	-143.37	-144.83	-144.77	-144.68
10.0000	-144.26	-144.15	-144.19	-144.87	-144.85	-144.69
12.5000	-144.66	-144.59	-144.66	-144.95	-144.95	-144.68
16.0000	-144.83	-144.95	-145.06	-145.09	-144.86	-144.72
20.0000	-145.12	-144.84	-144.87	-144.92	-144.79	-144.64
25.0000	-145.19	-145.17	-145.53	-145.01	-144.96	-144.75
31.5000	-145.41	-145.43	-145.23	-145.10	-145.02	-144.78
40.0000	-146.21	-146.27	-146.31	-146.09	-145.90	-145.70

Digitizer #8

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-122.63	-117.09	-117.42			
0.0125	-122.63	-117.09	-117.42			
0.0160	-122.68	-117.55	-117.46			
0.0200	-122.68	-117.55	-117.46			
0.0250	-123.38	-117.53	-117.86			
0.0315	-123.30	-117.68	-117.94			
0.0400	-123.49	-118.40	-118.01			
0.0500	-123.82	-118.51	-118.25			
0.0630	-124.12	-119.75	-118.92			
0.0800	-124.39	-119.62	-118.70			
0.1000	-124.77	-119.70	-119.28	-126.85	-127.87	-123.78
0.1250	-125.30	-120.34	-120.06	-127.42	-128.79	-124.10
0.1600	-125.85	-121.05	-120.70	-128.19	-129.47	-125.08
0.2000	-126.31	-121.55	-121.59	-128.96	-130.21	-126.40
0.2500	-126.91	-122.66	-122.13	-130.06	-131.10	-127.30
0.3150	-127.09	-123.77	-122.39	-130.96	-132.32	-128.21
0.4000	-128.01	-124.70	-123.24	-131.80	-133.46	-128.79
0.5000	-128.48	-126.28	-124.27	-133.18	-134.69	-129.38
0.6300	-128.83	-128.20	-124.49	-134.75	-136.57	-130.47
0.8000	-129.00	-129.68	-124.69	-136.82	-137.71	-131.45
1.0000	-129.68	-131.96	-125.58	-139.23	-138.91	-132.58
1.2500	-131.39	-134.53	-127.07	-141.33	-140.61	-133.42
1.6000	-135.55	-137.39	-132.03	-143.22	-142.56	-134.94
2.0000	-138.99	-139.36	-136.27	-144.34	-143.49	-136.10
2.5000	-140.34	-140.54	-139.54	-144.97	-144.10	-137.92
3.1500	-141.40	-141.30	-141.03	-145.09	-144.40	-139.10
4.0000	-142.09	-141.90	-142.00	-145.20	-144.57	-140.63
5.0000	-142.74	-142.66	-142.71	-145.27	-144.68	-141.77
6.3000	-143.41	-143.38	-143.39	-145.28	-144.72	-142.84
8.0000	-144.03	-143.96	-143.92	-145.32	-144.81	-143.70
10.0000	-144.34	-144.45	-144.40	-145.39	-144.84	-144.27
12.5000	-144.65	-144.74	-144.74	-145.39	-144.89	-144.69
16.0000	-144.94	-145.04	-145.09	-145.33	-144.88	-144.90
20.0000	-145.09	-145.21	-145.18	-145.37	-144.92	-145.04
25.0000	-145.24	-145.31	-145.32	-145.42	-144.94	-145.13
31.5000	-145.31	-145.41	-145.42	-145.39	-144.95	-145.11
40.0000	-146.31	-146.47	-146.43	-146.41	-145.85	-146.16

Digitizer #9

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-125.81	-120.41	-124.99			
0.0125	-126.30	-120.63	-125.14			
0.0160	-126.87	-121.30	-126.25			
0.0200	-126.85	-121.30	-126.77			
0.0250	-128.68	-123.42	-129.22			
0.0315	-129.38	-124.49	-129.95			
0.0400	-130.77	-125.62	-130.55			
0.0500	-130.94	-125.85	-130.09			
0.0630	-131.64	-126.67	-131.75			
0.0800	-132.10	-127.09	-131.88			
0.1000	-132.51	-127.57	-133.23	-129.23	-141.10	-136.69
0.1250	-133.85	-129.28	-133.80	-130.28	-141.68	-137.74
0.1600	-135.77	-132.59	-136.24	-132.18	-142.21	-141.47
0.2000	-136.78	-133.70	-137.16	-133.45	-142.63	-142.19
0.2500	-137.66	-135.11	-137.62	-134.79	-142.85	-143.08
0.3150	-138.34	-135.97	-138.36	-136.04	-143.16	-144.00
0.4000	-138.66	-137.04	-138.56	-137.28	-143.72	-144.33
0.5000	-139.06	-138.02	-138.77	-138.59	-144.11	-144.54
0.6300	-139.21	-138.25	-139.01	-139.13	-144.18	-144.75
0.8000	-139.51	-138.68	-139.14	-139.99	-144.41	-144.85
1.0000	-139.64	-138.97	-139.36	-140.60	-144.45	-144.91
1.2500	-140.07	-139.38	-139.61	-141.27	-144.47	-145.12
1.6000	-140.17	-139.67	-139.96	-142.01	-144.67	-145.16
2.0000	-140.61	-140.13	-140.18	-142.38	-144.54	-145.04
2.5000	-140.94	-140.46	-140.74	-142.92	-144.72	-145.16
3.1500	-141.58	-141.07	-141.25	-143.29	-144.83	-145.18
4.0000	-142.21	-141.75	-141.92	-143.74	-144.82	-145.13
5.0000	-142.89	-142.45	-142.73	-144.07	-144.90	-145.12
6.3000	-143.47	-143.12	-143.35	-144.26	-144.94	-145.15
8.0000	-144.06	-143.76	-143.93	-144.52	-144.95	-145.14
10.0000	-144.48	-144.23	-144.40	-144.67	-145.02	-145.13
12.5000	-144.87	-144.65	-144.76	-144.74	-145.05	-145.16
16.0000	-145.13	-144.91	-145.04	-144.85	-145.10	-145.13
20.0000	-145.29	-145.14	-145.21	-144.91	-145.10	-145.14
25.0000	-145.41	-145.27	-145.38	-144.91	-145.13	-145.17
31.5000	-145.47	-145.36	-145.49	-144.96	-145.16	-145.20
40.0000	-146.58	-146.49	-146.62	-145.96	-146.11	-146.17

Digitizer #10

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-118.18	-114.77	-116.72			
0.0125	-118.77	-116.80	-118.27			
0.0160	-119.72	-117.68	-119.48			
0.0200	-122.28	-120.28	-120.65			
0.0250	-122.43	-121.37	-121.67			
0.0315	-123.36	-121.76	-123.02			
0.0400	-124.66	-122.81	-123.59			
0.0500	-125.32	-123.99	-123.97			
0.0630	-126.10	-124.89	-124.80			
0.0800	-128.07	-126.07	-126.08			
0.1000	-129.26	-127.87	-127.65	-135.34	-133.94	-134.19
0.1250	-130.74	-128.96	-129.06	-136.96	-135.11	-136.47
0.1600	-132.97	-131.83	-131.36	-139.70	-136.43	-139.37
0.2000	-134.40	-133.43	-133.22	-141.19	-137.67	-141.00
0.2500	-135.75	-134.87	-134.96	-142.53	-139.02	-142.25
0.3150	-136.88	-136.28	-135.88	-143.24	-140.44	-143.19
0.4000	-137.76	-137.11	-136.89	-144.05	-141.63	-143.74
0.5000	-138.29	-137.68	-137.79	-144.29	-142.13	-144.02
0.6300	-138.94	-137.92	-138.17	-144.37	-142.77	-144.20
0.8000	-139.27	-138.97	-138.90	-144.68	-143.30	-144.59
1.0000	-139.32	-139.13	-139.37	-144.93	-143.94	-144.59
1.2500	-139.58	-139.58	-139.65	-145.03	-144.42	-144.69
1.6000	-140.06	-139.85	-139.94	-145.15	-144.60	-144.86
2.0000	-140.33	-140.13	-140.57	-145.11	-144.66	-144.76
2.5000	-140.75	-140.69	-140.97	-145.12	-144.95	-144.83
3.1500	-141.25	-141.46	-141.52	-145.12	-144.92	-144.77
4.0000	-141.89	-141.88	-142.18	-145.13	-145.05	-144.66
5.0000	-142.63	-142.57	-142.81	-145.14	-145.05	-144.78
6.3000	-143.14	-143.47	-143.36	-145.15	-145.07	-144.84
8.0000	-144.21	-143.85	-143.67	-145.24	-145.09	-144.82
10.0000	-144.28	-144.46	-144.30	-145.16	-145.12	-144.87
12.5000	-144.68	-144.76	-144.70	-145.31	-145.21	-144.87
16.0000	-144.89	-144.91	-144.93	-145.24	-145.16	-144.75
20.0000	-145.14	-145.17	-145.06	-145.12	-145.22	-144.72
25.0000	-145.15	-145.39	-145.35	-145.24	-145.29	-144.73
31.5000	-145.36	-145.33	-145.28	-145.23	-145.32	-144.89
40.0000	-146.32	-146.24	-146.48	-146.21	-146.19	-145.94

Digitizer #11

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-120.68	-115.89	-119.42			
0.0125	-120.78	-116.50	-118.87			
0.0160	-121.15	-116.50	-118.87			
0.0200	-124.63	-121.08	-123.38			
0.0250	-126.25	-121.71	-123.83			
0.0315	-127.52	-123.20	-125.54			
0.0400	-128.47	-124.95	-126.86			
0.0500	-128.86	-125.58	-127.64			
0.0630	-129.80	-125.59	-128.13			
0.0800	-129.85	-125.66	-128.22			
0.1000	-129.86	-125.92	-128.31	-134.56	-133.58	-133.13
0.1250	-130.07	-125.97	-128.17	-134.48	-133.61	-133.03
0.1600	-129.57	-125.86	-128.07	-134.48	-133.73	-133.13
0.2000	-129.48	-125.67	-127.73	-134.43	-133.79	-133.16
0.2500	-129.45	-125.89	-127.73	-134.41	-133.88	-133.26
0.3150	-129.39	-126.11	-127.95	-134.30	-134.30	-133.37
0.4000	-129.49	-126.25	-128.13	-134.34	-134.45	-133.79
0.5000	-130.05	-126.83	-128.33	-134.54	-134.71	-134.15
0.6300	-130.12	-127.11	-128.33	-134.87	-135.10	-134.94
0.8000	-130.74	-127.61	-128.87	-135.31	-135.53	-135.57
1.0000	-131.13	-128.17	-129.22	-135.52	-135.99	-136.00
1.2500	-131.70	-128.91	-129.84	-136.16	-136.44	-137.09
1.6000	-133.38	-130.68	-131.24	-137.56	-137.47	-138.73
2.0000	-134.82	-132.54	-132.57	-138.66	-138.62	-140.40
2.5000	-136.37	-134.41	-134.79	-140.23	-140.07	-142.05
3.1500	-138.40	-137.16	-137.20	-141.97	-141.49	-143.34
4.0000	-140.53	-140.05	-139.96	-143.26	-142.43	-144.09
5.0000	-141.86	-141.93	-141.97	-144.54	-143.42	-144.75
6.3000	-142.88	-143.00	-143.10	-145.13	-143.88	-145.06
8.0000	-143.63	-143.73	-143.83	-145.24	-144.16	-145.06
10.0000	-144.14	-144.21	-144.27	-145.39	-144.50	-145.08
12.5000	-144.55	-144.58	-144.64	-145.36	-144.73	-145.23
16.0000	-144.87	-144.87	-144.93	-145.21	-144.77	-144.96
20.0000	-145.09	-145.07	-145.11	-145.31	-145.01	-145.22
25.0000	-145.23	-145.17	-145.24	-145.39	-145.10	-145.21
31.5000	-145.35	-145.28	-145.30	-145.34	-145.18	-145.22
40.0000	-146.38	-146.28	-146.34	-146.27	-146.10	-146.15

Digitizer #12

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-118.70	-117.51	-116.05			
0.0125	-119.18	-117.71	-116.59			
0.0160	-119.18	-117.71	-116.59			
0.0200	-120.64	-118.26	-118.76			
0.0250	-121.34	-118.37	-118.78			
0.0315	-121.75	-118.78	-118.96			
0.0400	-122.06	-119.50	-118.61			
0.0500	-122.06	-119.50	-118.72			
0.0630	-122.98	-119.98	-120.02			
0.0800	-123.51	-120.36	-120.72			
0.1000	-123.70	-120.81	-121.21	-126.25	-126.08	-124.16
0.1250	-124.16	-121.39	-121.40	-126.69	-126.63	-124.64
0.1600	-124.43	-121.61	-121.77	-127.88	-127.13	-125.82
0.2000	-125.39	-122.57	-122.67	-128.67	-127.45	-126.32
0.2500	-125.98	-123.08	-123.44	-129.86	-128.22	-127.05
0.3150	-126.66	-123.86	-123.96	-130.90	-128.85	-128.41
0.4000	-127.53	-125.01	-124.85	-131.82	-129.38	-129.09
0.5000	-128.57	-126.05	-126.22	-133.03	-129.86	-130.13
0.6300	-128.75	-126.78	-126.63	-133.60	-130.18	-130.74
0.8000	-130.69	-128.82	-128.55	-135.28	-130.74	-132.23
1.0000	-132.22	-130.79	-130.29	-136.41	-131.05	-133.12
1.2500	-133.52	-132.36	-131.90	-137.73	-131.20	-134.39
1.6000	-135.47	-135.10	-134.48	-139.19	-131.73	-135.86
2.0000	-137.29	-136.90	-136.33	-140.27	-131.90	-136.83
2.5000	-139.12	-138.98	-138.81	-141.27	-132.21	-137.88
3.1500	-140.36	-140.40	-140.46	-142.04	-132.41	-139.09
4.0000	-141.32	-141.47	-141.69	-142.26	-132.83	-139.78
5.0000	-142.13	-142.23	-142.48	-142.87	-133.45	-140.62
6.3000	-142.97	-143.06	-143.28	-143.24	-134.29	-141.35
8.0000	-143.66	-143.77	-143.97	-143.39	-135.45	-142.15
10.0000	-144.20	-144.22	-144.48	-143.85	-137.00	-142.94
12.5000	-144.63	-144.61	-144.76	-144.24	-138.56	-143.54
16.0000	-144.93	-144.90	-145.09	-144.38	-140.52	-144.19
20.0000	-145.13	-145.08	-145.23	-144.59	-142.04	-144.56
25.0000	-145.28	-145.21	-145.34	-144.79	-143.47	-144.70
31.5000	-145.35	-145.27	-145.41	-144.81	-144.40	-145.06
40.0000	-146.39	-146.29	-146.41	-145.83	-145.79	-146.17

Digitizer #13

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-119.22	-118.60	-118.54			
0.0125	-120.28	-120.25	-119.95			
0.0160	-120.17	-120.25	-119.95			
0.0200	-119.98	-119.80	-120.31			
0.0250	-120.43	-119.96	-120.31			
0.0315	-121.04	-121.08	-121.40			
0.0400	-121.07	-121.12	-121.67			
0.0500	-121.32	-121.17	-121.11			
0.0630	-121.56	-121.99	-122.67			
0.0800	-121.83	-122.55	-122.85			
0.1000	-122.89	-122.78	-122.82	-126.85	-126.08	-128.18
0.1250	-123.19	-123.14	-123.74	-127.73	-127.39	-128.97
0.1600	-124.35	-124.15	-124.02	-129.10	-129.03	-129.85
0.2000	-126.36	-125.98	-125.17	-131.21	-130.58	-131.07
0.2500	-127.67	-127.30	-126.46	-133.42	-132.85	-132.60
0.3150	-129.43	-129.63	-128.41	-135.83	-135.75	-134.90
0.4000	-132.03	-132.13	-131.31	-138.52	-139.16	-137.66
0.5000	-134.66	-134.50	-133.86	-141.15	-141.15	-140.30
0.6300	-136.64	-136.80	-136.25	-143.19	-142.78	-142.25
0.8000	-138.24	-138.31	-137.87	-144.14	-144.09	-143.58
1.0000	-138.82	-139.07	-138.58	-144.50	-144.43	-144.03
1.2500	-139.23	-139.54	-139.05	-144.69	-144.80	-144.53
1.6000	-139.57	-139.94	-139.47	-144.75	-144.99	-144.65
2.0000	-139.99	-140.33	-139.79	-144.84	-145.02	-144.63
2.5000	-140.43	-140.78	-140.31	-144.84	-145.17	-144.62
3.1500	-141.07	-141.36	-140.96	-144.86	-145.21	-144.66
4.0000	-141.73	-142.05	-141.75	-144.91	-145.15	-144.84
5.0000	-142.37	-142.62	-142.51	-144.90	-145.25	-144.92
6.3000	-143.09	-143.33	-143.21	-144.75	-145.28	-144.89
8.0000	-143.73	-143.91	-143.89	-144.87	-145.27	-145.00
10.0000	-144.31	-144.37	-144.33	-144.86	-145.24	-145.04
12.5000	-144.63	-144.73	-144.72	-144.94	-145.29	-145.10
16.0000	-144.92	-144.98	-144.98	-144.92	-145.29	-145.25
20.0000	-145.12	-145.18	-145.18	-144.90	-145.32	-145.23
25.0000	-145.27	-145.32	-145.31	-144.98	-145.31	-145.32
31.5000	-145.34	-145.35	-145.39	-145.00	-145.37	-145.29
40.0000	-146.39	-146.38	-146.42	-145.89	-146.27	-146.30

Digitizer #14

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-125.76	-114.34	-111.50			
0.0125	-126.27	-114.67	-111.66			
0.0160	-126.65	-115.24	-112.24			
0.0200	-127.36	-115.50	-112.60			
0.0250	-127.92	-116.34	-113.41			
0.0315	-129.32	-117.10	-114.18			
0.0400	-130.21	-118.94	-115.95			
0.0500	-131.26	-119.99	-117.07			
0.0630	-132.87	-122.24	-119.34			
0.0800	-133.50	-123.33	-120.44			
0.1000	-134.65	-125.05	-121.99	-130.63	-128.71	-130.08
0.1250	-136.07	-128.09	-125.02	-132.21	-130.87	-132.52
0.1600	-136.65	-130.27	-127.97	-134.89	-133.26	-135.85
0.2000	-137.73	-133.61	-131.00	-136.76	-134.17	-137.70
0.2500	-138.34	-135.16	-133.14	-138.39	-135.44	-139.71
0.3150	-138.65	-136.69	-135.57	-140.87	-137.13	-141.46
0.4000	-139.08	-138.20	-137.53	-142.39	-138.32	-142.96
0.5000	-139.31	-138.79	-138.68	-143.49	-139.56	-143.64
0.6300	-139.59	-139.15	-139.09	-143.97	-140.40	-144.20
0.8000	-139.59	-139.32	-139.54	-144.55	-141.69	-144.48
1.0000	-139.93	-139.62	-140.09	-144.66	-142.22	-144.49
1.2500	-140.07	-139.71	-140.12	-144.91	-143.09	-144.78
1.6000	-140.14	-140.21	-140.67	-145.03	-143.61	-144.93
2.0000	-140.53	-140.37	-140.96	-145.01	-143.94	-144.96
2.5000	-140.98	-141.12	-141.33	-145.15	-144.34	-145.11
3.1500	-141.64	-141.45	-141.70	-145.11	-144.57	-145.09
4.0000	-142.33	-142.02	-142.59	-145.19	-144.73	-145.10
5.0000	-142.79	-142.45	-142.98	-145.23	-144.83	-145.16
6.3000	-143.45	-143.20	-143.61	-145.15	-144.90	-145.16
8.0000	-144.24	-143.75	-144.16	-145.06	-144.94	-145.22
10.0000	-144.33	-144.18	-144.45	-144.67	-144.85	-145.12
12.5000	-144.80	-144.63	-144.86	-145.27	-145.09	-145.23
16.0000	-145.04	-144.93	-145.12	-145.30	-145.11	-145.26
20.0000	-145.09	-145.05	-145.21	-145.16	-145.10	-145.23
25.0000	-145.43	-145.23	-145.32	-145.22	-144.99	-145.10
31.5000	-145.35	-145.15	-145.23	-145.25	-145.17	-145.07
40.0000	-146.15	-146.26	-146.31	-146.28	-146.03	-146.12

Digitizer #15

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-122.36	-121.16	-115.98			
0.0125	-123.89	-122.39	-117.49			
0.0160	-125.36	-123.34	-119.18			
0.0200	-128.11	-125.80	-122.14			
0.0250	-128.89	-126.65	-122.99			
0.0315	-128.61	-126.18	-122.38			
0.0400	-129.32	-126.55	-123.32			
0.0500	-131.21	-127.20	-125.46			
0.0630	-132.27	-128.27	-127.07			
0.0800	-133.27	-128.98	-128.40			
0.1000	-134.00	-129.84	-130.24	-136.79	-137.58	-139.49
0.1250	-134.99	-130.56	-131.52	-138.24	-139.06	-140.58
0.1600	-135.82	-131.78	-133.22	-140.03	-140.77	-141.57
0.2000	-136.44	-132.54	-135.15	-141.51	-141.91	-142.54
0.2500	-136.61	-133.28	-135.99	-142.56	-142.74	-143.07
0.3150	-137.41	-134.11	-137.03	-143.34	-143.50	-143.50
0.4000	-137.73	-135.14	-137.72	-143.81	-144.06	-144.10
0.5000	-138.11	-135.79	-137.65	-144.05	-144.06	-144.20
0.6300	-138.19	-136.14	-137.08	-143.38	-143.74	-144.16
0.8000	-138.83	-136.87	-138.70	-144.64	-144.48	-144.48
1.0000	-138.85	-137.14	-138.88	-145.03	-144.68	-144.69
1.2500	-139.47	-137.74	-139.20	-144.99	-144.72	-144.83
1.6000	-139.80	-138.34	-139.67	-145.15	-144.96	-144.95
2.0000	-140.09	-138.78	-140.01	-145.07	-144.87	-144.86
2.5000	-140.46	-139.57	-140.50	-145.14	-144.97	-145.07
3.1500	-141.27	-140.23	-141.15	-145.13	-145.05	-145.07
4.0000	-141.80	-141.13	-141.84	-145.01	-144.86	-145.04
5.0000	-142.55	-142.05	-142.52	-145.14	-144.96	-144.96
6.3000	-143.30	-142.89	-143.30	-145.17	-145.04	-145.20
8.0000	-143.90	-143.65	-143.84	-145.21	-144.94	-145.15
10.0000	-144.40	-144.21	-144.32	-145.24	-145.00	-145.11
12.5000	-144.67	-144.59	-144.75	-145.02	-145.01	-145.20
16.0000	-144.97	-144.96	-145.00	-145.17	-145.05	-145.09
20.0000	-145.14	-145.12	-145.19	-145.07	-144.99	-145.10
25.0000	-145.31	-145.28	-145.34	-144.82	-145.06	-145.34
31.5000	-145.40	-145.37	-145.40	-145.29	-145.15	-145.23
40.0000	-146.41	-146.40	-146.40	-146.25	-145.97	-146.06

Digitizer #16

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-116.25	-125.14	-116.67			
0.0125	-117.75	-126.05	-118.26			
0.0160	-119.82	-127.26	-120.26			
0.0200	-122.10	-130.11	-122.50			
0.0250	-123.07	-131.12	-123.76			
0.0315	-124.38	-132.15	-125.44			
0.0400	-126.58	-132.88	-127.66			
0.0500	-127.75	-134.06	-128.18			
0.0630	-130.03	-135.14	-129.63			
0.0800	-130.99	-135.57	-131.04			
0.1000	-132.68	-136.70	-132.40	-136.83	-138.06	-128.71
0.1250	-134.01	-137.29	-133.33	-138.37	-139.68	-129.18
0.1600	-135.07	-137.37	-134.28	-139.27	-141.14	-129.83
0.2000	-136.17	-137.92	-135.09	-140.55	-142.14	-130.46
0.2500	-137.13	-138.26	-135.81	-141.21	-142.95	-131.08
0.3150	-137.82	-138.67	-136.36	-142.27	-143.94	-131.77
0.4000	-138.24	-138.87	-137.01	-142.61	-144.47	-132.93
0.5000	-138.74	-138.86	-137.52	-143.04	-144.61	-133.66
0.6300	-139.34	-138.91	-138.06	-143.24	-144.85	-134.44
0.8000	-139.51	-139.08	-138.52	-143.52	-144.90	-135.67
1.0000	-139.65	-139.29	-138.78	-143.55	-145.01	-136.56
1.2500	-140.09	-139.79	-139.24	-143.87	-145.10	-137.70
1.6000	-140.06	-139.98	-139.61	-144.02	-145.19	-138.78
2.0000	-140.34	-140.37	-140.20	-144.28	-145.15	-139.40
2.5000	-140.93	-140.97	-140.45	-144.53	-145.15	-140.30
3.1500	-141.43	-141.61	-141.32	-144.64	-145.18	-140.92
4.0000	-142.13	-141.95	-142.04	-144.82	-145.19	-141.44
5.0000	-142.87	-142.77	-142.62	-145.04	-145.19	-141.97
6.3000	-143.60	-143.51	-143.11	-145.08	-145.18	-142.50
8.0000	-144.02	-143.87	-143.78	-145.11	-145.13	-142.98
10.0000	-144.51	-144.38	-144.55	-145.17	-145.18	-143.43
12.5000	-144.89	-144.54	-144.91	-145.31	-145.20	-143.95
16.0000	-145.14	-144.92	-144.95	-145.20	-145.18	-144.27
20.0000	-145.37	-145.26	-145.23	-145.32	-145.18	-144.54
25.0000	-145.39	-145.13	-145.38	-145.37	-145.20	-144.75
31.5000	-145.55	-145.42	-145.26	-145.39	-145.21	-144.78
40.0000	-146.33	-146.38	-146.37	-146.25	-146.10	-145.83

Digitizer #17

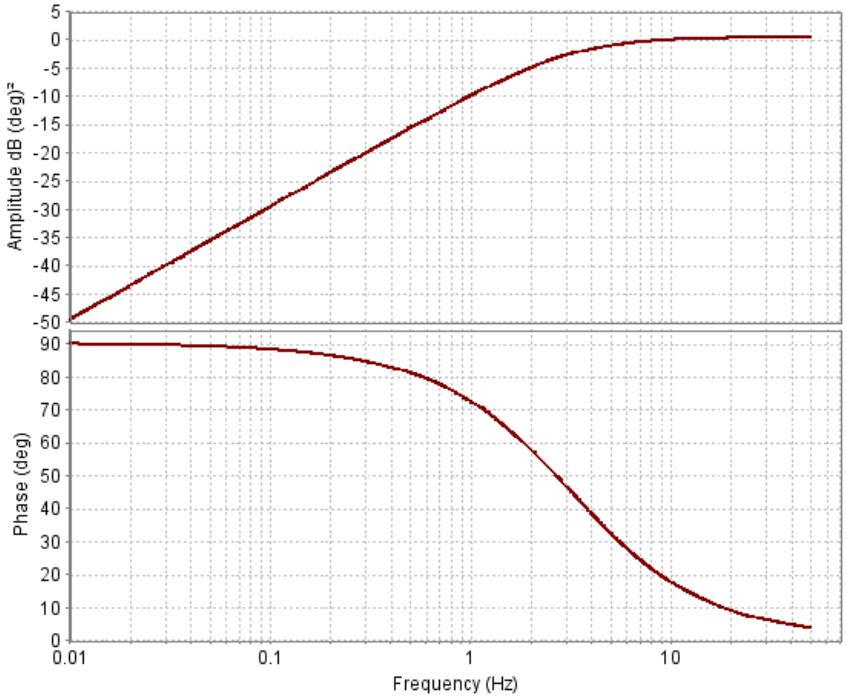
Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-116.14	-113.94	-112.28			
0.0125	-117.19	-114.67	-113.60			
0.0160	-117.19	-114.67	-113.60			
0.0200	-118.56	-117.09	-115.09			
0.0250	-118.56	-117.09	-115.24			
0.0315	-118.70	-116.56	-115.23			
0.0400	-119.70	-117.43	-116.12			
0.0500	-119.69	-118.00	-117.33			
0.0630	-121.01	-118.25	-118.02			
0.0800	-121.50	-118.77	-118.42			
0.1000	-123.06	-120.50	-120.71	-128.81	-126.24	-130.52
0.1250	-124.05	-122.25	-121.82	-130.28	-127.49	-131.70
0.1600	-125.57	-123.26	-122.95	-132.10	-128.34	-134.15
0.2000	-127.73	-125.67	-125.26	-134.28	-129.79	-136.29
0.2500	-130.43	-127.93	-127.75	-136.92	-131.00	-138.66
0.3150	-132.81	-130.44	-130.06	-139.46	-131.79	-140.75
0.4000	-135.34	-133.65	-132.48	-141.25	-132.37	-142.50
0.5000	-136.57	-135.37	-134.76	-142.29	-132.58	-143.26
0.6300	-136.10	-134.19	-134.02	-142.29	-132.69	-143.50
0.8000	-137.53	-135.68	-135.84	-143.16	-133.03	-143.78
1.0000	-137.73	-135.56	-135.28	-143.32	-133.04	-143.88
1.2500	-139.10	-138.67	-138.68	-144.44	-133.33	-144.74
1.6000	-139.80	-139.73	-139.83	-144.90	-133.57	-144.98
2.0000	-140.07	-139.63	-139.87	-144.86	-133.88	-144.91
2.5000	-140.67	-140.62	-140.90	-144.91	-134.49	-145.13
3.1500	-141.31	-141.12	-141.35	-145.09	-135.01	-145.09
4.0000	-141.99	-141.79	-142.00	-144.97	-135.68	-145.14
5.0000	-142.64	-142.54	-142.79	-145.06	-136.59	-145.12
6.3000	-143.34	-143.30	-143.44	-145.09	-137.82	-145.23
8.0000	-143.95	-143.90	-144.00	-145.08	-139.21	-145.10
10.0000	-144.44	-144.41	-144.47	-145.11	-140.36	-145.10
12.5000	-144.73	-144.77	-144.82	-145.22	-141.64	-145.08
16.0000	-145.08	-145.11	-145.09	-145.06	-142.79	-145.12
20.0000	-145.24	-145.26	-145.25	-145.07	-143.35	-144.84
25.0000	-145.36	-145.39	-145.36	-145.15	-143.82	-145.23
31.5000	-145.47	-145.47	-145.42	-145.20	-144.30	-145.28
40.0000	-146.57	-146.54	-146.42	-146.07	-145.60	-146.21

Digitizer #18

Frequency (Hz)	BHZ (dB rel 1 V^2/Hz)	BH2 (dB rel 1 V^2/Hz)	BH1 (dB rel 1 V^2/Hz)	SHZ (dB rel 1 V^2/Hz)	SH2 (dB rel 1 V^2/Hz)	SH1 (dB rel 1 V^2/Hz)
0.0100	-114.56	-113.22	-111.46			
0.0125	-114.56	-113.57	-111.56			
0.0160	-115.08	-114.21	-111.62			
0.0200	-115.70	-115.06	-111.97			
0.0250	-115.88	-115.14	-112.17			
0.0315	-116.38	-115.98	-113.67			
0.0400	-117.17	-116.47	-114.23			
0.0500	-117.92	-117.25	-114.41			
0.0630	-118.62	-117.88	-115.01			
0.0800	-119.12	-118.82	-115.66			
0.1000	-120.67	-119.86	-116.59	-125.77	-128.35	-124.55
0.1250	-121.27	-120.24	-117.27	-126.95	-128.50	-125.42
0.1600	-122.73	-122.20	-118.53	-128.03	-130.54	-127.33
0.2000	-123.45	-123.09	-119.38	-129.65	-131.16	-129.05
0.2500	-125.34	-124.46	-120.31	-130.42	-132.51	-129.50
0.3150	-126.82	-126.32	-121.59	-132.54	-134.33	-131.60
0.4000	-129.21	-128.61	-124.49	-134.89	-136.53	-134.59
0.5000	-131.79	-131.05	-127.49	-136.72	-138.55	-136.48
0.6300	-134.45	-133.95	-130.52	-139.55	-140.91	-139.56
0.8000	-136.70	-136.60	-134.65	-141.78	-143.09	-141.69
1.0000	-138.95	-138.23	-137.63	-142.79	-144.07	-143.15
1.2500	-139.47	-138.77	-138.87	-143.52	-144.42	-143.80
1.6000	-140.17	-139.58	-139.56	-143.52	-144.63	-144.16
2.0000	-140.38	-139.75	-139.93	-143.60	-144.64	-144.31
2.5000	-141.01	-140.28	-140.55	-143.70	-144.75	-144.58
3.1500	-141.58	-140.85	-141.10	-143.78	-144.86	-144.65
4.0000	-142.16	-141.35	-141.84	-143.79	-144.82	-144.72
5.0000	-142.82	-142.26	-142.59	-143.90	-144.95	-144.86
6.3000	-143.38	-143.06	-143.28	-143.99	-144.86	-144.85
8.0000	-144.03	-143.46	-143.76	-144.16	-144.93	-144.91
10.0000	-144.62	-144.09	-144.42	-144.25	-144.97	-144.97
12.5000	-144.84	-144.81	-144.67	-144.38	-144.99	-145.01
16.0000	-145.00	-145.01	-144.89	-144.44	-144.96	-144.94
20.0000	-145.02	-145.18	-145.00	-144.58	-144.99	-145.05
25.0000	-145.40	-145.17	-145.30	-144.64	-145.00	-145.07
31.5000	-145.56	-145.51	-145.35	-144.69	-145.05	-145.12
40.0000	-146.48	-146.37	-146.36	-145.60	-146.02	-146.03

APPENDIX C: RESPONSE MODELS

SHDAS Broadband Channel Preamplifier Response



Sensitivity:
1 at 10.0 Hz

Poles:

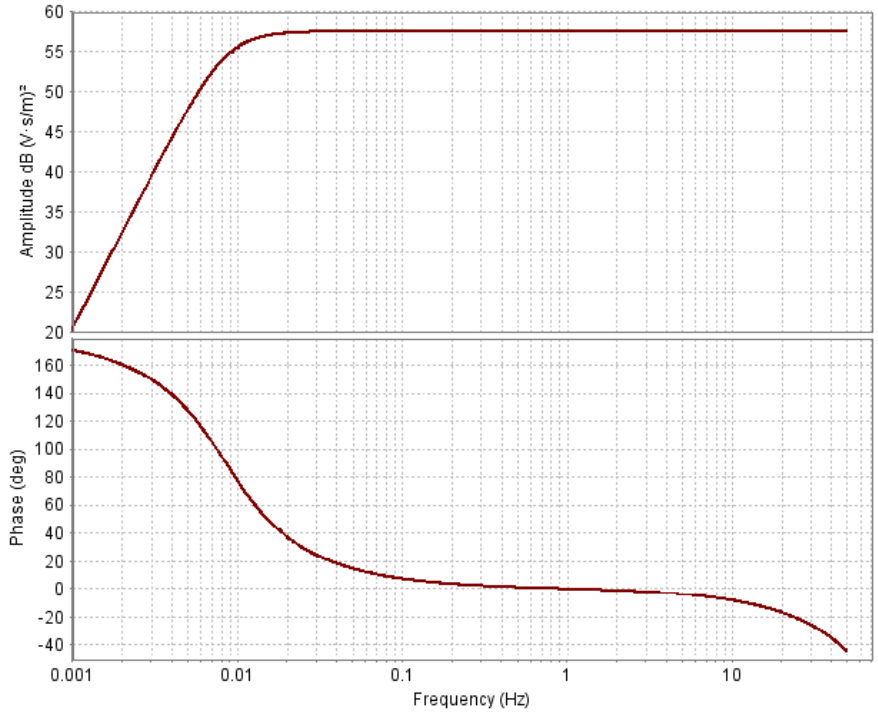
-20.1062	0.0

Zeros:

0.0	0.0

A:
1.04995

Nanometrics Trillium OBS Response



Sensitivity:
750 V·s/m at 10.0 Hz

Poles:

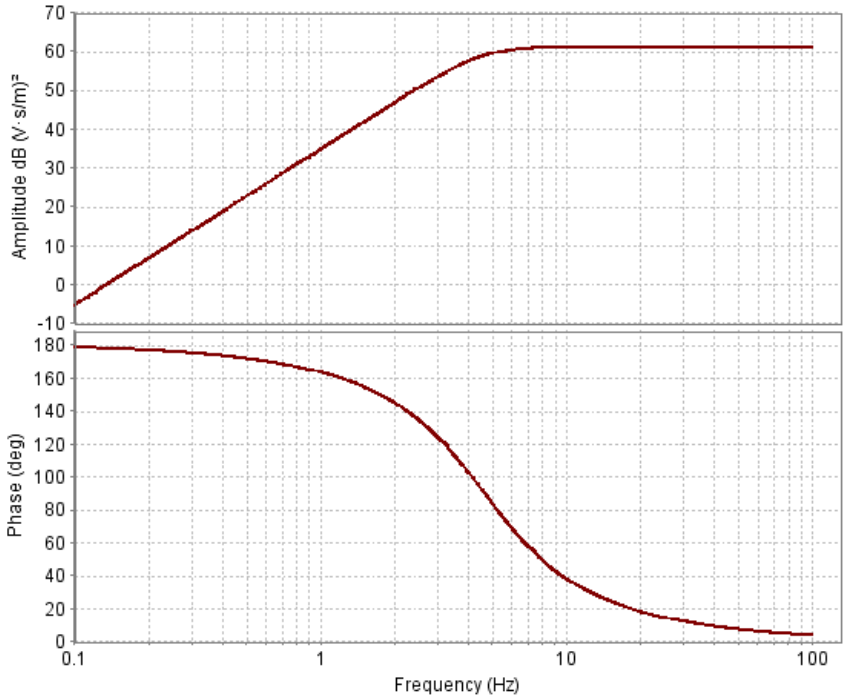
-15000.0	0.0
-6900.0	0.0
-4900.0	4700.0
-4900.0	-4700.0
-836.0	1522.0
-836.0	-1522.0
-370.0	467.0
-370.0	-467.0
-343.0	0.0
-0.0391	0.03702
-0.0391	-0.03702

Zeros:

-1960.0	0.0
-1490.0	1740.0
-1490.0	-1740.0
-392.0	0.0
0.0	0.0
0.0	0.0

A:
325.96152E12 MV·s/m

Navy OBS Response



Sensitivity:
1,150 V·s/m at 10.0 Hz

Poles:

-19.396	21.887
-19.396	-21.887

Zeros:

0.0	0.0
0.0	0.0

A:
1,147.02568 V·s/m

APPENDIX D: CALIBRATION

The following SNL Primary Standards Laboratory calibration report for the Agilent 3458A Meter Serial #45044336 provides traceability for all of the results in this digitizer evaluation.

PRIMARY STANDARDS
LABORATORY

Sandia National Laboratories, Albuquerque, New Mexico 87185-0665

Limited Calibration Certificate

Document #: 6567273_11667868

Item Identification

Asset Number	6567273
Description	Meter,Multifunction
Model	3458A
Serial #	MY45044336
Manufacturer	Agilent Technologies
Customer Asset Id	N/A
Purchase Order	N/A
Customer	Ground-Based Monitoring R&E 05752
Custodian	Merchant, Bion J.
Location	SNLNM/TA1/758/1042
Date of Receipt	April 11, 2016
Dates Tested (Start – End)	April 19, 2016 - April 19, 2016
Date Approved	April 21, 2016
Calibration Expiration Date	April 21, 2017

Calibration Description

Calibration Lab	PSL-ELECTRICAL
Calibration Procedure, rev.	HP 3458A, 4.1
Temperature	23 deg C
Humidity	40 %RH
Barometric Pressure	N/A mmHg
As Found Condition	PASS
As Left Condition	PASS
Software Used	MET/CAL 8.3.2.3
Tamper Seal	None

Page **1** of **8**
6567273_11667868

Calibration Specifications and Results

This instrument (Agilent/HP 3458A) was tested using the SNL Primary Standards Laboratory's Multimeter/ Multifunction Station MMS #9300 and is certified to be within the following LIMITED specifications:

DC Volts:
± (11 ppm of reading + 10 ppm of range) 100 mV range
± (10 ppm of reading + 1 ppm of range) 1 V range
± (10 ppm of reading + 0.2 ppm of range) 10 V range
± (12 ppm of reading + 0.3 ppm of range) 100 V range
± (12 ppm of reading + 0.1 ppm of range) 1000 V range

AC Volts:
10 Hz to 40 Hz ± (0.2% of reading + 0.002% of range) 10 mV to 100 V ranges
40 Hz to 20 kHz ± (0.045% of reading + 0.002% of range) 10 mV to 100 V ranges
40 Hz to 20 kHz ± (0.08% of reading + 0.002% of range) 1000 V range
20 kHz to 50 kHz ± (0.1% of reading + 0.011% of range) 10 mV range
20 kHz to 50 kHz ± (0.1% of reading + 0.002% of range) 100 mV to 100 V ranges
50 kHz to 100 kHz ± (0.5% of reading + 0.011% of range) 10 mV range
50 kHz to 100 kHz ± (0.2% of reading + 0.002% of range) 100 mV to 100 V ranges
100 kHz to 300 kHz ± (4% of reading + 0.02% of range) 10 mV range
100 kHz to 300 kHz ± (1% of reading + 0.01% of range) 100 mV to 10 V ranges
100 kHz to 200 kHz ± (1% of reading + 0.01% of range) 100 V range

NOTE: 700 V RMS maximum on 1000 VAC range

4-wire Ohms:
± (100 ppm of reading + 10 ppm of range) 10 Ω range
± (50 ppm of reading + 5 ppm of range) 100 Ω range
± (50 ppm of reading + 1 ppm of range) 1 KΩ to 100 KΩ ranges
± (100 ppm of reading + 2 ppm of range) 1 MΩ range
± (200 ppm of reading + 10 ppm of range) 10 MΩ range
± (500 ppm of reading + 10 ppm of range) 100 MΩ range
± (2% of reading + 10 ppm of range) 1 GΩ range

DC Current
± (10% of reading + 0.01% of range) 100 nA range
± (3.0% of reading + 0.01% of range) 1 µA range
± (0.3% of reading + 0.001% of range) 10 µA
± (0.04% of reading + 0.01% of range) 100 µA and 1 A ranges
± (0.02% of reading + 0.005% of range) 1 mA, 10 mA, and 100 mA ranges

AC Current:
20 Hz to 1 kHz ± (0.15% of reading + 0.02% of range) 100 µA range
20 Hz to 5 kHz ± (0.15% of reading + 0.02% of range) 1 mA to 100 mA ranges
40 Hz to 5 kHz ± (0.15% of reading + 0.02% of range) 1 A range
5 kHz to 10 kHz ± (0.5% of reading + 0.02% of range) 1 mA to 100 mA ranges

Frequency:
10 Hz to 40 Hz ± 0.05% of reading
40 Hz to 10 MHz ± 0.01% of reading

Note 1: Measurement setup configuration is defined in manufacturer's accuracy statement footnotes.
Note 2: Additional errors due to deviations in setup configuration shall be added by the user to the specifications in this certificate.
Note 3: Contact the Primary Standards Laboratory for assistance with uncertainty calculations as needed.

PRIMARY STANDARDS
LABORATORY

Sandia National Laboratories, Albuquerque, New Mexico 87185-0665

Calibration Data Report

Primary Electrical Lab

Unit Under Test:	Agilent 3458A Multimeter	Test Result:	PASS
Asset Number:	6567273	Test Type:	FOUND-LEFT
Serial Number:	MY45044336	Calibration Date:	4/19/2016
Procedure Name:	HP 3458A	Temperature:	23 °C
Revision:	4.1	Humidity:	40 %
Calibrated By:	Brian Liddle		

- Test Type is defined as follows:
  - AS-FOUND Data collected prior to adjustment and/or repair
  - AS-LEFT Data collected after adjustment and/or repair
  - FOUND-LEFT Data collected without adjustment and/or repair
- Test Uncertainty Ratio (TUR) is defined as:
  - TUR = Specification Limit / Uncertainty of the Measurement
- A hash (#) appended to the TUR indicates a guardbanded measurement
  - Guardbanded limits are smaller than the specification limits
  - Guardbanding performed according to the Primary Standards Laboratory Operations Procedure (PSL-PRO-001)
- An asterisk (*) appended to the TUR indicates use of a Test Accuracy Ratio (TAR) instead of a TUR
  - TAR = Specification Limit / Accuracy of the Standard

COMMENTS:

Standards Used

Asset #	Description	Due Date
11123	Keithley 5155-9 1 Gohm resistor	5/8/2016
20280	FLUKE 5700A/EP MULTI-FUNCTION CALIBRATOR	5/21/2016
20563	FLUKE 5790A CALIBRATOR	6/11/2016
44972	Fluke 5725A Amplifier	12/15/2016
6651332	Agilent 33250A Funtion/Arbitrary Waveform Generato	2/17/2017

Test Results

Test Description	True Value	Lower Limit	Measured Value	Upper Limit	Units	TUR	% Tol	Status
MMS: 9300								
SOFTWARE USED: Met/Cal Version 8.3.2								
CALIBRATION MANUAL: Agilent Technologies 3458A Multimeter Calbration Manual, Edition 6, October 2013 PN 03458-90017								
LIMITED CALIBRATION: PSL specifications are larger than manufacturer's specifications reported in Factory User Manual. This is a limitation of the PSL.								
The internal temperature of the 3458A is 38.2 deg.C								
DC Volts								
100.00000 mV		99.99790	100.00026	100.00210	mV	1.91	13	
-100.00000 mV		-100.00210	-100.00026	-99.99790	mV	1.91	12	
1.00000000 V		0.99998900	1.00000426	1.00001100	V	2.08	39	
-1.00000000 V		-1.00001100	-1.00000376	-0.99998900	V	2.08	34	
-10.0000000 V		-10.0001020	-10.0000442	-9.9998980	V	3.09	43	
-5.0000000 V		-5.0000520	-5.0000220	-4.9999480	V	2.89	42	
-2.0000000 V		-2.0000220	-2.0000087	-1.9999780	V	2.22	40	
2.0000000 V		1.9999780	2.0000098	2.0000220	V	2.22	45	

PRIMARY STANDARDS LABORATORY

Sandia National Laboratories, Albuquerque, New Mexico 87185-0665

Test Results

Test Description	True Value	Lower Limit	Measured Value	Upper Limit	Units	TUR	% Tol	Status
5.0000000 V		4.9999480	5.0000217	5.0000520	V	2.89	42	
10.0000000 V		9.9998980	10.0000414	10.0001020	V	3.09	41	
100.000000 V		99.998770	100.000473	100.001230	V	2.46	38	
1000.00000 V		999.98790	1000.00740	1000.01210	V	1.83	61	
DC Current								
100.000 nA		89.990	100.004	110.010	nA	1.85	0	
1.000000 µA		0.969900	0.999995	1.030100	µA	5.5	0	
10.000000 µA		9.969900	9.999814	10.030100	µA	5.2	1	
100.00000 µA		99.95000	99.99822	100.05000	µA	5.4	4	
1.0000000 mA		0.9997500	0.9999874	1.0002500	mA	6.8	5	
10.000000 mA		9.997500	9.999892	10.002500	mA	7.1	4	
100.00000 mA		99.97500	99.99911	100.02500	mA	5.6	4	
1.0000000 A		0.9995000	0.9999633	1.0005000	A	6.2	7	
Resistance								
10.00000 Ohm	9.999738	9.99864	9.99999	10.00084	Ohm	5.2	23	
100.00000 Ohm	99.997810	99.99231	100.00045	100.00331	Ohm	5.9	48	
1.0000000 kOhm	0.99998540	0.9999344	0.9999993	1.0000364	kOhm	6.5	27	
10.000000 kOhm	10.0004610	9.999951	10.000616	10.000971	kOhm	6.5	30	
100.00000 kOhm	100.002660	99.99756	100.00396	100.00776	kOhm	5.1	25	
1.0000000 MOhm	0.99999850	0.9998965	1.0000129	1.0001005	MOhm	5.7	14	
10.000000 MOhm	9.9991090	9.997009	9.999450	10.001209	MOhm	5.8	16	
100.00000 MOhm	100.002540	99.95154	100.01719	100.05354	MOhm	5.5	29	
1.00177000 GOhm		0.9817246	1.0025796	1.0218154	GOhm	>10	4	
AC Current								
100.0000 µA @ 20 Hz		99.8300	99.9360	100.1700	µA	6.8	38	
100.0000 µA @ 45 Hz		99.8300	99.9828	100.1700	µA	8.9	10	
100.0000 µA @ 1 kHz		99.8300	99.9799	100.1700	µA	8.9	12	
1.000000 mA @ 20 Hz		0.998300	0.999490	1.001700	mA	8.9	30	
1.000000 mA @ 45 Hz		0.998300	0.999970	1.001700	mA	>10	2	
1.000000 mA @ 5 kHz		0.998300	1.000203	1.001700	mA	5.9	12	
1.000000 mA @ 10 kHz		0.994800	1.000524	1.005200	mA	3.25	10	
10.00000 mA @ 20 Hz		9.98300	9.99500	10.01700	mA	8.9	29	
10.00000 mA @ 45 Hz		9.98300	9.99976	10.01700	mA	>10	1	
10.00000 mA @ 5 kHz		9.98300	10.00156	10.01700	mA	7.1	9	
10.00000 mA @ 10 kHz		9.94800	10.00336	10.05200	mA	3.47	6	
100.0000 mA @ 20 Hz		99.8300	99.9538	100.1700	mA	8.9	27	
100.0000 mA @ 45 Hz		99.8300	100.0021	100.1700	mA	>10	1	
100.0000 mA @ 5 kHz		99.8300	100.0365	100.1700	mA	7.7	22	
100.0000 mA @ 10 kHz		99.4800	100.0753	100.5200	mA	4.7	15	
1.000000 A @ 40 Hz		0.998300	0.999983	1.001700	A	6.1	1	
1.000000 A @ 5 kHz		0.998300	1.000845	1.001700	A	3.62	50	
AC Volts								
10.00000 mV @ 10 Hz	9.999700	9.97950	9.99786	10.01990	mV	7.2	9	
10.00000 mV @ 40 Hz	9.999500	9.99480	9.99820	10.00420	mV	2.94	28	
10.00000 mV @ 20 kHz	10.000600	9.99590	9.99784	10.00530	mV	2.94	59	
10.00000 mV @ 50 kHz	10.000500	9.98940	9.99520	10.01160	mV	4.1	48	
10.00000 mV @ 100 kHz	9.998700	9.94761	9.97930	10.04979	mV	>10	38	
10.00000 mV @ 300 kHz	10.002200	9.60011	9.84535	10.40429	mV	>10	39	
100.0000 mV @ 10 Hz	99.99860	99.7966	99.9988	100.2006	mV	>10	0	
100.0000 mV @ 40 Hz	99.99540	99.9484	99.9987	100.0424	mV	>10	7	
100.0000 mV @ 20 kHz	99.99670	99.9497	99.9896	100.0437	mV	>10	15	
100.0000 mV @ 50 kHz	99.99520	99.8932	99.9876	100.0972	mV	>10	7	
100.0000 mV @ 100 kHz	99.99110	99.7891	99.9644	100.1931	mV	>10	13	
100.0000 mV @ 300 kHz	99.95760	98.9480	99.8441	100.9672	mV	>10	11	
1.000000 V @ 10 Hz	0.9999979	0.997978	1.000049	1.002018	V	>10	3	
1.000000 V @ 40 Hz	0.9999989	0.999529	1.000036	1.000469	V	>10	8	
1.000000 V @ 20 kHz	1.0000057	0.999536	0.999939	1.000476	V	>10	14	
1.000000 V @ 50 kHz	1.0000106	0.998991	0.999956	1.001031	V	>10	5	
1.000000 V @ 100 kHz	1.0000169	0.997997	0.999976	1.002037	V	>10	2	
1.000000 V @ 300 kHz	1.0001949	0.990093	1.000926	1.010297	V	>10	7	
10.00000 V @ 10 Hz	9.999904	9.97970	10.00061	10.02010	V	>10	3	

PRIMARY STANDARDS LABORATORY

Sandia National Laboratories, Albuquerque, New Mexico 87185-0665

Test Results

Test Description	True Value	Lower Limit	Measured Value	Upper Limit	Units	TUR	% Tol	Status
10.00000 V @ 40 Hz	9.999897	9.99520	10.00047	10.00460	V	>10	12	
10.00000 V @ 20 kHz	9.999992	9.99529	9.99966	10.00469	V	>10	7	
10.00000 V @ 50 kHz	9.999998	9.98980	9.99957	10.01020	V	>10	4	
10.00000 V @ 100 kHz	10.000192	9.97999	9.99783	10.02039	V	>10	12	
10.00000 V @ 300 kHz	10.002567	9.90154	9.99290	10.10359	V	>10	10	
100.0000 V @ 10 Hz	99.99950	99.7975	100.0055	100.2015	V	>10	3	
100.0000 V @ 40 Hz	99.99931	99.9523	100.0034	100.0463	V	>10	9	
100.0000 V @ 20 kHz	100.00023	99.9532	99.9914	100.0472	V	>10	19	
100.0000 V @ 50 kHz	100.00119	99.8992	99.9977	100.1032	V	>10	3	
100.0000 V @ 100 kHz	100.00481	99.8028	100.0021	100.2068	V	>10	1	
100.0000 V @ 200 kHz	100.02200	99.0119	100.0431	101.0322	V	>10	2	
700.0000 V @ 40 Hz	700.00920	699.4292	699.9419	700.5892	V	>10	12	
700.0000 V @ 20 kHz	700.04250	699.4625	699.6944	700.6225	V	>10	60	
FREQUENCY								
10.00000 Hz @ 1 V		9.995000	10.000127	10.005000	Hz	>10	3	
40.00000 Hz @ 1 V		39.996000	40.000382	40.004000	Hz	>10	10	
100.00000 Hz @ 1 V		99.990000	100.000878	100.010000	Hz	>10	9	
1000.0000 Hz @ 1 V		999.90000	1000.00849	1000.10000	Hz	>10	8	
10000.0000 Hz @ 1 V		9999.00000	10000.08202	10001.00000	Hz	>10	8	
20000.0000 Hz @ 1 V		19998.00000	20000.16404	20002.00000	Hz	>10	8	
50000.0000 Hz @ 1 V		49995.00000	50000.41008	50005.00000	Hz	>10	8	
100.00000 kHz @ 1 V		99.990000	100.000830	100.010000	kHz	>10	8	
500.00000 kHz @ 1 V		499.950000	500.004101	500.050000	kHz	>10	8	
1.000000 MHz @ 1 V		0.9999000	1.0000083	1.0001000	MHz	>10	8	
2.000000 MHz @ 1 V		1.9998000	2.0000166	2.0002000	MHz	>10	8	
4.000000 MHz @ 1 V		3.9996000	4.0000330	4.0004000	MHz	>10	8	
6.000000 MHz @ 1 V		5.9994000	6.0000496	6.0006000	MHz	>10	8	
8.000000 MHz @ 1 V		7.9992000	8.0000658	8.0008000	MHz	>10	8	
10.000000 MHz @ 1 V		9.9990000	10.0000830	10.0010000	MHz	>10	8	

***** End of Test Results *****

Limitations
PSL specifications are larger than manufacturer's specifications reported in Factory User Manual. This is a limitation of the PSL.

Equipment (Standard) Used

Asset #	Description	Model	Expires
6651332	Generator,Function	33250A	February 18, 2017
44972	Amplifier	5725A	December 15, 2016
20563	Standard,Measurement,AC	5790A	June 11, 2016
20280	Calibrator,Multifunction	5700A/EP3	May 21, 2016
11123	Resistor,Standard	5155-9	May 08, 2016

Traceability

Values and the associated uncertainties supplied by the Primary Standards Lab (PSL) are traceable to the SI through one or more of the following:

1. Reference standards whose values are disseminated by the National Institute of Standards and Technology (United States of America) or, where appropriate, to the national metrological institute of another nation participating in the CIPM MRA;
2. Reference standards whose values are disseminated by a laboratory that has demonstrated competence, measurement capability, and traceability for those values;
3. The accepted value(s) of fundamental physical phenomena (intrinsic standards);
4. Ratio(s) or other non-maintained standards established by either a self-calibration and/or a direct calibration technique;
5. Standards maintained and disseminated by the PSL in special cases and where warranted, such as consensus standards where no national or international standards exist;

Note 1: This certificate or report shall not be reproduced except in full, without the advance written approval of the Primary Standards Lab at Sandia National Laboratories.

Note 2: For National Voluntary Laboratory Accreditation Program (NVLAP) accredited capabilities, the PSL at Sandia National Laboratories is accredited by NVLAP for the specific scope of accreditation under Laboratory Code 105002-0. This certificate or report shall not be used by the customer to claim product endorsement by NVLAP, the Primary Standards Laboratory, Sandia National Laboratories or any agency of the U. S. Government.

Note 3: The as received condition of the standard, set of standards, or measurement equipment described herein was as expected, unless otherwise noted in the body of the certificate or report.

Note 4: The presence of names and titles under "Authorization" are properly authenticated electronic signatures conforming to the equivalent identification signatory requirements of ISO 17025:2005 5.10.2.j.

Authorization

Calibrated By:	Approved By:
Liddle, Brian David	Gerty, Donavon Robert
Metrologist	Technical Project Leader

End-of-Document

Distribution

1	MS0899	Technical Library	9536 (electronic copy)


Sandia National Laboratories