*LIGO Laboratory / LIGO Scientific Collaboration*

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**aLIGO HEPI L1 HAM5 Assembly Validation Report**

E1300926-V2

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Distribution of this document:

Advanced LIGO Project

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Introduction

This document summarizes the different tests which have been done to validate HEPI L1 HAM5. All tests were run after the payload installation was completed inside the chamber, in June 2013.

# Sub-Components Testing

* Kaman Inductive Position Sensors: calibration, linearity, factory data, noise measurements (E0900426 – HEPI Kaman Sensor Receiving Analysis - Results posted in the SVN )

***Note:*** these serial numbers have not been recorded at the time of install and are not hidden.

* HEPI actuator linearity test (E1100338 – aLIGO HEPI Actuators Test Results).

***Note:*** these serial numbers have not been recorded at the time of install but are still accessible and will be recorded.

* L4C test (Q0900007)

|  |  |  |
| --- | --- | --- |
|  | Horizontal | Vertical |
| Pier 1 |  | L41621 |
| Pier 2 |  | L41631 |
| Pier 3 |  | L41638 |
| Pier 4 |  | L41625 |

***Note:*** the Horizontal L4Cs have not been recorded at the time of install and are now really hard to access, that’s why the serial numbers do not appear a=on this table.

**Figures in SVN at:**

*/HEPI/L1/HAM5/Data/Figures/Spectra/Ground/*

* *hepi\_ham5\_l4c\_horiz\_huddle.png*
* *hpi\_ham5\_l4C\_vert\_huddle.png*

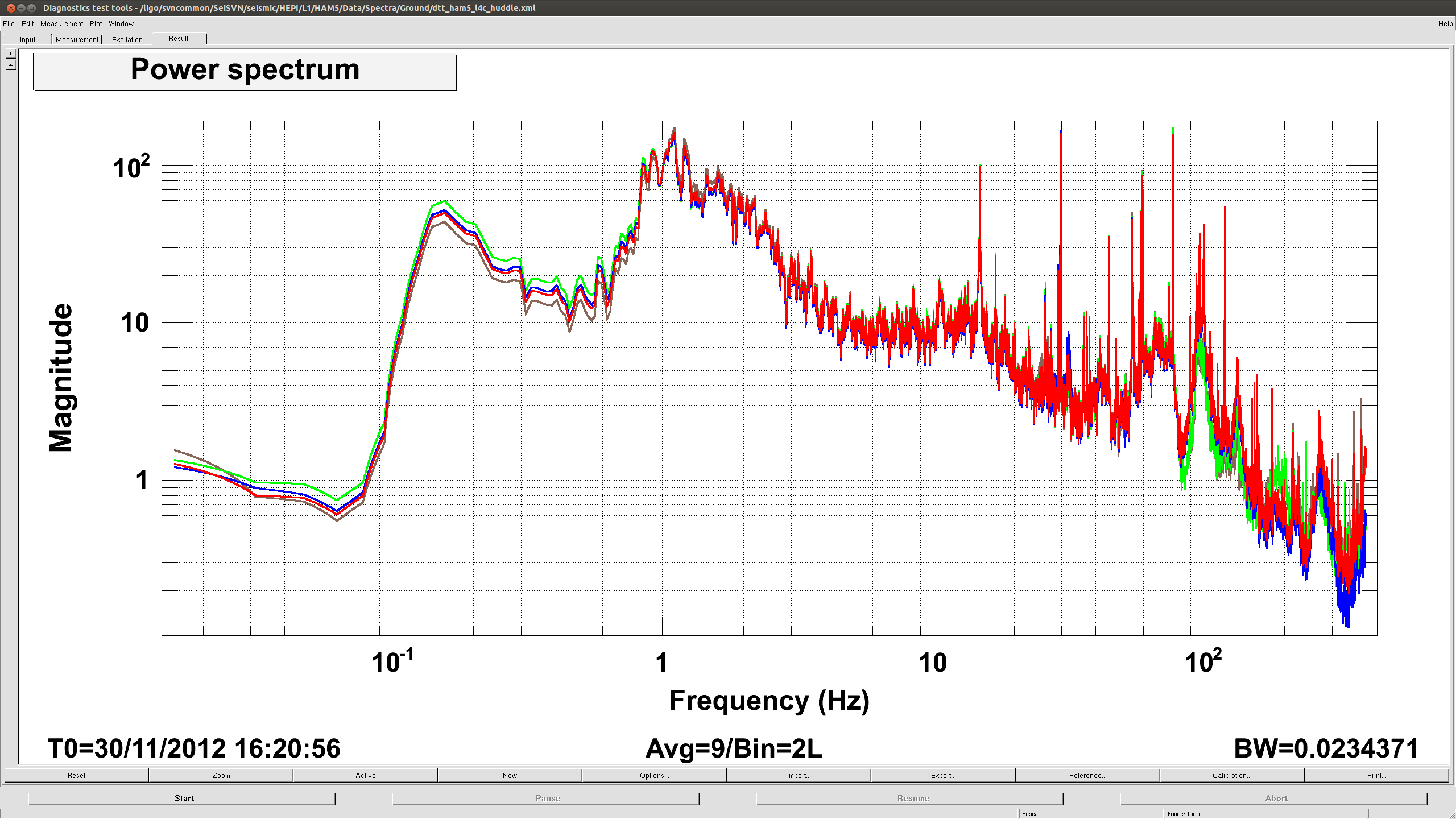


Figure 1: Power spectra of L1 HAM 5 horizontal L4Cs

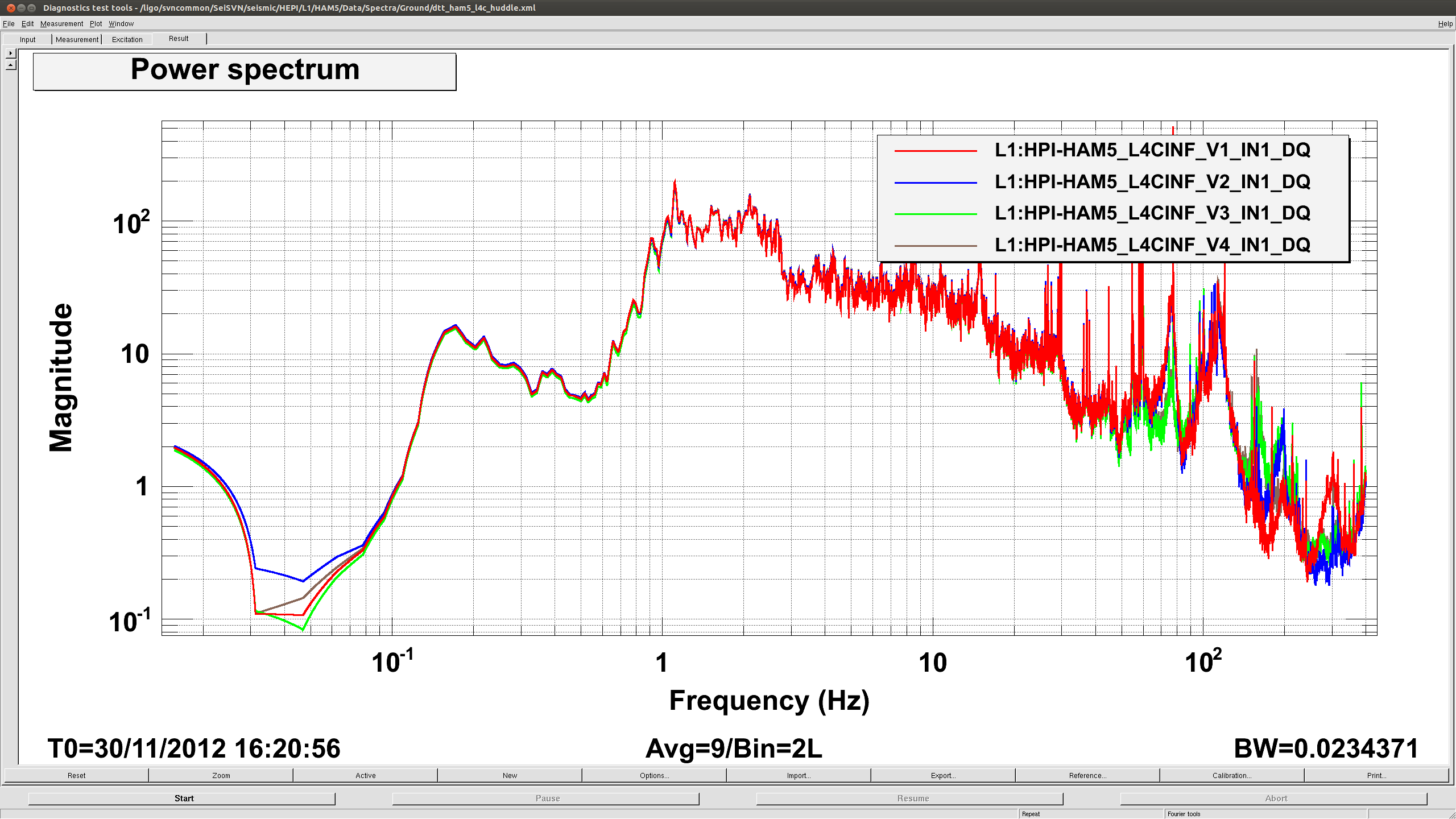


Figure 2: Power spectra of L1 HAM 5 horizontal L4Cs

# Assembly Validation

## Load Cells assembly

* Spring attachment

For the HAM HEPI springs, check the assembly per [D1003359](https://dcc.ligo.org/LIGO-D1003359).

* Load cell values

HAM HEPI load cell capacity → 2000 lbs



Left Spring

Right Spring

Figure 3: HAM-HEPI example at LASTI

|  |  |  |
| --- | --- | --- |
|  | **Left Spring (lbs)** | **Right Spring (lbs)** |
| **Pier 1** | 1279 | 1352 |
| **Pier 2** | 1301 | 1366 |
| **Pier 3** | 1100 | 1295 |
| **Pier 4** | 1479 | 1369 |

**Acceptance criteria:**

* The values must not exceed 80% of the load cell capacity (<1600lbs for HAM).

**Test result: Passed: X Failed: . Waived: . .**

## Bellows

The bellows are hard to access and tests are hard to proceed. After several discussions and brainstorming sessions, it has been decided not to measure the gaps on HEPI-HAM.

**Test result: Passed: Failed: . Waived: . X .**

## Boot Location

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Pier 1 | Pier 2 | Pier 3 | Pier 4 | Nominal |
| Tangential Left | 5.184 | 5.437 | 5.207 | 5.446 | 5.38 |
| Tangential Right | 5.462 | 5.218 | 5.454 | 5.225 | 5.38 |
| Radial Back | 1.233 | 1.172 | 1.196 | 1.127 | 1.17 |
| Radial Front | 1.302 | 1.352 | 1.393 | 1.188 | 1.42 |
| Vertical | 0.469 | 0.287 | 0.382 | 0.32 | 0.32 |

**Acceptance criteria:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Pier 1 | Pier 2 | Pier 3 | Pier 4 | Requirements |
| Tangential Left | -0.196 | 0.057 | -0.173 | 0.066 | +/- 0.20 |
| Tangential Right | 0.082 | -0.162 | 0.074 | -0.155 | +/- 0.20 |
| Radial Back | 0.063 | 0.002 | 0.026 | -0.043 | +/- 0.10 |
| Radial Front | -0.118 | -0.068 | -0.027 | -0.232 | +/- 0.15 |
| Vertical | 0.149 | -0.033 | 0.062 | 0 | +/- 0.20 |

***Note:*** usually this test can be waived if step 1.10 Linearity Test/Range of motion in the local basis passes because it means that the system has a full range of motion and is, therefore, free to move.

**Test result: Passed: Failed: X . Waived: . .**

## Check Stops Gaps

The stops must not touch the boot. There are 15 stops per boot, 5 per F bracket.

****

**#1**

**#2**

**#3**

**#4**

**#5**

**Bracket 1**

**Bracket 2**

**Bracket 3**

Figure 9: Locations of the boot’s stops

**Acceptance criteria:**

* A 0.062” shim must fit into the gaps



A 0.062” must fit into the gaps





Figure : Locations of the boot's gaps to measure

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Bracket 1** | | | | | | **Bracket 2** | | | | | | **Bracket 3** | | | | | |
|  | **Gap1** | **Gap2** | **Gap3** | **Gap4 above** | **Gap4 under** | **Gap5** | **Gap1** | **Gap2** | **Gap3** | **Gap4 above** | **Gap4 under** | **Gap5** | **Gap1** | **Gap2** | **Gap3** | **Gap4 above** | **Gap4 under** | **Gap5** |
| **Pier 1** | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go |
| **Pier 2** | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go |
| **Pier 3** | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go |
| **Pier 4** | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go | Go |

***Note:*** HAM 4 is currently in the locked position so the measurement of these gaps is pointless at this time. Measurements will be taken when HEPI will be unlocked on HAM 4.

**Test result: Passed: Failed: . Waived: . .**

## Gaps check

Four particular gaps need to be check.



Gap #1

Gap #2

***Note:* The F bracket has been removed for a better visibility**





Gap #3

Gap #4

Figure 11: Gaps which need to be checked

**Acceptance criteria:**

* a 0.08” shim must fit in these two gaps

Issues/difficulties/comments regarding this test: Gap#1 is tricky to reach. At LASTI, the solution found was to tape the shim to an extension (rod, rigid ruler, etc.).

Gap#2 should be reachable by hand.

Gap#3 and 4 are tricky, but should also be doable (no picture)

**Gap#1**



Figure : First gap to measure (on the first picture, we can see the tool used to measure that gap)

**Gap#2**



Figure : Second gap to measure

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Gap#1** | **Gap#2** | **Gap#3** | **Gap#4** |
| **Pier 1** | Go | Go | Go | Go |
| **Pier 2** | Go | Go | Go | Go |
| **Pier 3** | Go | Go | Go | Go |
| **Pier 4** | Go | Go | Go | Go |

***Note:*** usually this test can be waived if step 1.10 Linearity Test/Range of motion in the local basis passes because it means that the system has a full range of motion and is, therefore, free to move.

**Test result: Passed: Failed: . Waived: . X .**

## IPS Centering

**Scripts files for processing and plotting in SVN at:**

*/SeiSVN/seismic/HEPI/Common/Testing\_Functions\_HEPI/Offset\_STD\_IPS\_HEPI.m*

***Note:*** All the loops must be turned off during this test.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | H1 | H2 | H3 | H4 | V1 | V2 | V3 | V4 |
| Mean (counts) |  |  |  |  |  |  |  |  |
| Acceptance | +/- 15000 | +/- 15000 | +/- 15000 | +/- 15000 | +/- 15000 | +/- 15000 | +/- 15000 | +/- 15000 |

**Test result: Passed: Failed: . Waived: . .**

## Sensor ASD

**Scripts files for processing and plotting in SVN at:**

*/SeiSVN/seismic/HEPI/Common/Testing\_Functions\_HEPI/ASD\_Measurements\_Local\_HEPI.m*

**Data in SVN at:**

*SeiSVN/seismic/HEPI/L1/HAM5/Data/Perf\_Analysis/2013-06-24-HEPI\_Level1-ISI\_Level2/*

**Figures in SVN at:**

*/SeiSVN/seismic/HEPI/L1/HAM5/Data/* *Figures/Perf\_Analysis/2013-09-22-HEPI-locked/fig/*

Figure 14: L1 HAM 2 HEPI Sensor spectra Horizontal L4Cs

Figure 15: L1 HAM 2 HEPI Sensor spectra Vertical L4Cs

Figure 16: L1 HAM 2 HEPI Sensor spectra Horizontal IPSs

Figure 17: L1 HAM 2 HEPI Sensor spectra Vertical IPSs

Issues/difficulties/comments regarding this test:

**Acceptance criteria:**

**Test result: Passed: Failed: . Waived: . .**

## SUS-watchdogs interaction test

***Note:* This test will be obsolete very soon, as the payload-HEPI WD connection is planned for removal.**

. Set up a zero value on the payload watchdogs.

. Check that the payload watchdog screen of HEPI tripped.

. In the payload watchdog screen, click on the OVERRIDE button and reset the watchdog.

. Do the same process for all the payloads

**Acceptance criteria:**

* The HEPI must trip when the payload watchdogs are tripped
* The HEPI watchdogs could be reset when the OVERRIDE button is ON
* **Test result: Passed: X Failed: . Waived: . .**

***Note:*** When this test is done, reset everything (OVERRIDE button OFF, put back the value on the payload watchdog).

## Static Test local drive

**Scripts files for processing in SVN at:**

*/SeiSVN/seismic/HEPI/Common/Testing\_Functions\_HEPI/**Static\_Test\_Local\_Basis\_HEPI.m*

**Data in SVN at:**

*SeiSVN/seismic/HEPI/L1/HAM5/Data/Static\_Tests/*

. ***Drive of 100 counts (in progress)***

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | H1 | H2 | H3 | H4 | V1 | V2 | V3 | V4 |
| H1 | 8350.9418 | -5056.1049 | -327.0384 | -1879.51872 | -178.9088 | 209.3388 | 192.18836 | -370.0864 |
| H2 | -4104.049 | 8306.5349 | -1822.531974 | -448.11792 | 134.8916 | -100.465 | -301.80668 | 139.7868 |
| H3 | -233.5984 | -2065.5751 | 8170.4572 | -4615.56692 | 178.7694 | -183.7838 | -239.1095 | 118.1154 |
| H4 | -1807.7793 | -701.3897 | -4558.2268 | 9000.50088 | -488.2914 | 367.591 | -1.00976 | -441.0128 |
| V1 | -87.0864 | 1.56718 | 302.0506 | -174.51156 | 7490.8344 | 918.82254 | -1656.35338 | 784.3534 |
| V2 | 182.2748 | -404.56522 | -128.0876 | 486.57564 | 833.8752 | 7402.042 | 675.00182 | -1629.1482 |
| V3 | 309.8688 | -477.33554 | -80.087 | 272.82164 | -1436.731 | 1099.12212 | 7236.42762 | 695.124 |
| V4 | -177.839 | 74.78868 | 291.7698 | -126.46464 | 955.694 | -1414.8926 | 824.44686 | 7487.4108 |

Table 1: Main couplings and cross couplings for 100count offset

. ***Drive of 1000 counts (in progress)***

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | H1 | H2 | H3 | H4 | V1 | V2 | V3 | V4 |
| H1 | 8350.9418 | -5056.1049 | -327.0384 | -1879.51872 | -178.9088 | 209.3388 | 192.18836 | -370.0864 |
| H2 | -4104.049 | 8306.5349 | -1822.531974 | -448.11792 | 134.8916 | -100.465 | -301.80668 | 139.7868 |
| H3 | -233.5984 | -2065.5751 | 8170.4572 | -4615.56692 | 178.7694 | -183.7838 | -239.1095 | 118.1154 |
| H4 | -1807.7793 | -701.3897 | -4558.2268 | 9000.50088 | -488.2914 | 367.591 | -1.00976 | -441.0128 |
| V1 | -87.0864 | 1.56718 | 302.0506 | -174.51156 | 7490.8344 | 918.82254 | -1656.35338 | 784.3534 |
| V2 | 182.2748 | -404.56522 | -128.0876 | 486.57564 | 833.8752 | 7402.042 | 675.00182 | -1629.1482 |
| V3 | 309.8688 | -477.33554 | -80.087 | 272.82164 | -1436.731 | 1099.12212 | 7236.42762 | 695.124 |
| V4 | -177.839 | 74.78868 | 291.7698 | -126.46464 | 955.694 | -1414.8926 | 824.44686 | 7487.4108 |

Table 2: Main couplings and cross couplings for 1000 count offset

. ***Drive of 5000 counts (Nominal value handled by testing script)***

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | H1 | H2 | H3 | H4 | V1 | V2 | V3 | V4 |
| H1 |  |  |  |  |  |  |  |  |
| H2 |  |  |  |  |  |  |  |  |
| H3 |  |  |  |  |  |  |  |  |
| H4 |  |  |  |  |  |  |  |  |
| V1 |  |  |  |  |  |  |  |  |
| V2 |  |  |  |  |  |  |  |  |
| V3 |  |  |  |  |  |  |  |  |
| V4 |  |  |  |  |  |  |  |  |

Table 3: Main couplings and cross couplings for 5000 count offset

Issues/difficulties encountered during this test:

**Acceptance criteria:**

* The results in these three tables must be the same (within xxx%)

**Test result: Passed: Failed: . Waived: . .**

## Linearity Test/Range of motion in the local basis

**Scripts files for processing and plotting in SVN at:**

*/SeiSVN/seismic/HEPI/Common/Testing\_Functions\_HEPI/Linearity\_Test\_Awgstream\_HEPI.m*

**Data in SVN at:**

*SeiSVN/seismic/HEPI/L1/HAM5/Data/Linearity\_Test/*

**Figures in SVN at:**

*/SeiSVN/seismic/HEPI/L1/HAM5/Data/Figures/Linearity\_Test/*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Slopes | Offsets | Average Slope | Difference / Average in % |
| H1 |  |  |  |  |
| H2 |  |  |  |
| H3 |  |  |  |
| H4 |  |  |  |
| V1 |  |  |  |  |
| V2 |  |  |  |
| V3 |  |  |  |
| V4 |  |  |  |

Figure 18: Linearity Test

**Scripts files for processing in SVN at:**

*/SeiSVN/seismic/HEPI/Common/Testing\_Functions\_HEPI/Static\_Test\_Local\_Basis\_HEPI.m*

**Data in SVN at:**

*SeiSVN/seismic/HEPI/L1/* *HAM5/Data/Static\_Tests/*

* *L1\_HPI\_HAM5\_Range\_Of\_Motion\_20130514.mat*

|  |  |  |  |
| --- | --- | --- | --- |
|  | Positive Drive | Negative Drive | Amplitude |
| H1 | 29365.74 | -26446.4 | 55812.1 |
| H2 | 32188.48 | -23484.6 | 55673.06 |
| H3 | 23490.39 | -27781.9 | 51272.25 |
| H4 | 31041.29 | -27862.5 | 58903.8 |
| V1 | 29177.26 | -18673.7 | 47851 |
| V2 | 28438.13 | -13917.6 | 42355.72 |
| V3 | 30154.86 | -19951.5 | 50106.32 |
| V4 | 27923.13 | -23359.4 | 51282.51 |

Table 4: Range of Motion

Issues/difficulties encountered during this test:

**Acceptance criteria:**

* For the linearity test, the results in these three tables must be the same (within +/- 20% compared to the average slopes)
* For the range of motion, the sign must be positive for a positive drive and negative for a negative drive, and the amplitude must be bigger than 40000 counts.

**Test result: Passed: X Failed: . Waived: . .**

## Actuator Plate to Shields gap

***Note:* Perform this test ONLY if the range of motion test failed.**

Figure : Locations of the actuator gaps to check if Step 1.10 Linearity Test/Range of motion in the local basis failed



Gap#3

Gap#2

Gap#1

Three gaps per actuator need to be checked as shown on Figure 19: Locations of the actuator gaps to check if Step 1.10 Linearity Test/Range of motion in the local basis failed .

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Horizontal** | | | **Vertical** | | |
|  | **Gap #1** | **Gap #2** | **Gap #3** | **Gap #1** | **Gap #2** | **Gap #3** |
| **Pier 1** | Go | Go | Go | Go | Go | Go |
| **Pier 2** | Go | Go | Go | Go | Go | Go |
| **Pier 3** | Go | Go | Go | Go | Go | Go |
| **Pier 4** | Go | Go | Go | Go | Go | Go |

**Acceptance criteria:**

* A 0.1” shim must fit into the gap #1
* A 0.05 shim must fit into gap #2 and #3

**Test result: Passed: Failed: . Waived: . X .**

## Valve Check

**Scripts files for processing and plotting in SVN at:**

*/SeiSVN/seismic/HEPI/L1/HAM5/Scripts/Valve\_Check/plot\_valve\_check.m*

*/SeiSVN/seismic/HEPI/L1/HAM5/Scripts/Valve\_Check*

**Figures in SVN at:**

*/SeiSVN/seismic/HEPI/L1/HAM5/Data/Figures/Valve\_Check/Individual\_Tests/Valve\_Check\_25-Jun-2013\_09:08:16.fig*

*/SeiSVN/seismic/HEPI/L1/HAM2/Data/Figures/Valve\_Check/Evolution/* *L1\_HAM5\_L4C\_Valve\_Check\_From\_09-May-2013\_Until\_25-Jun-2013.fig*

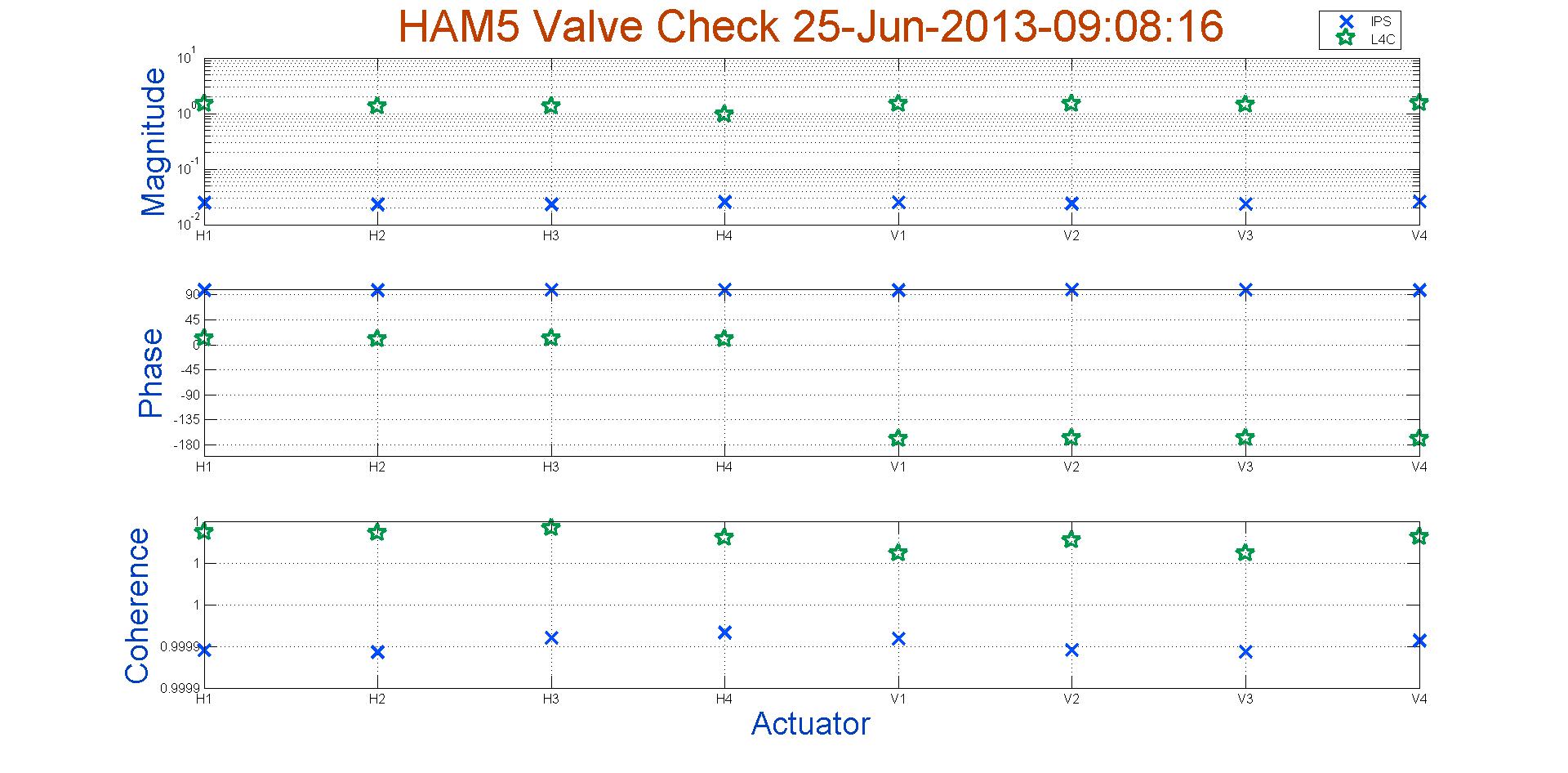


Figure 20: Valve check individual plot

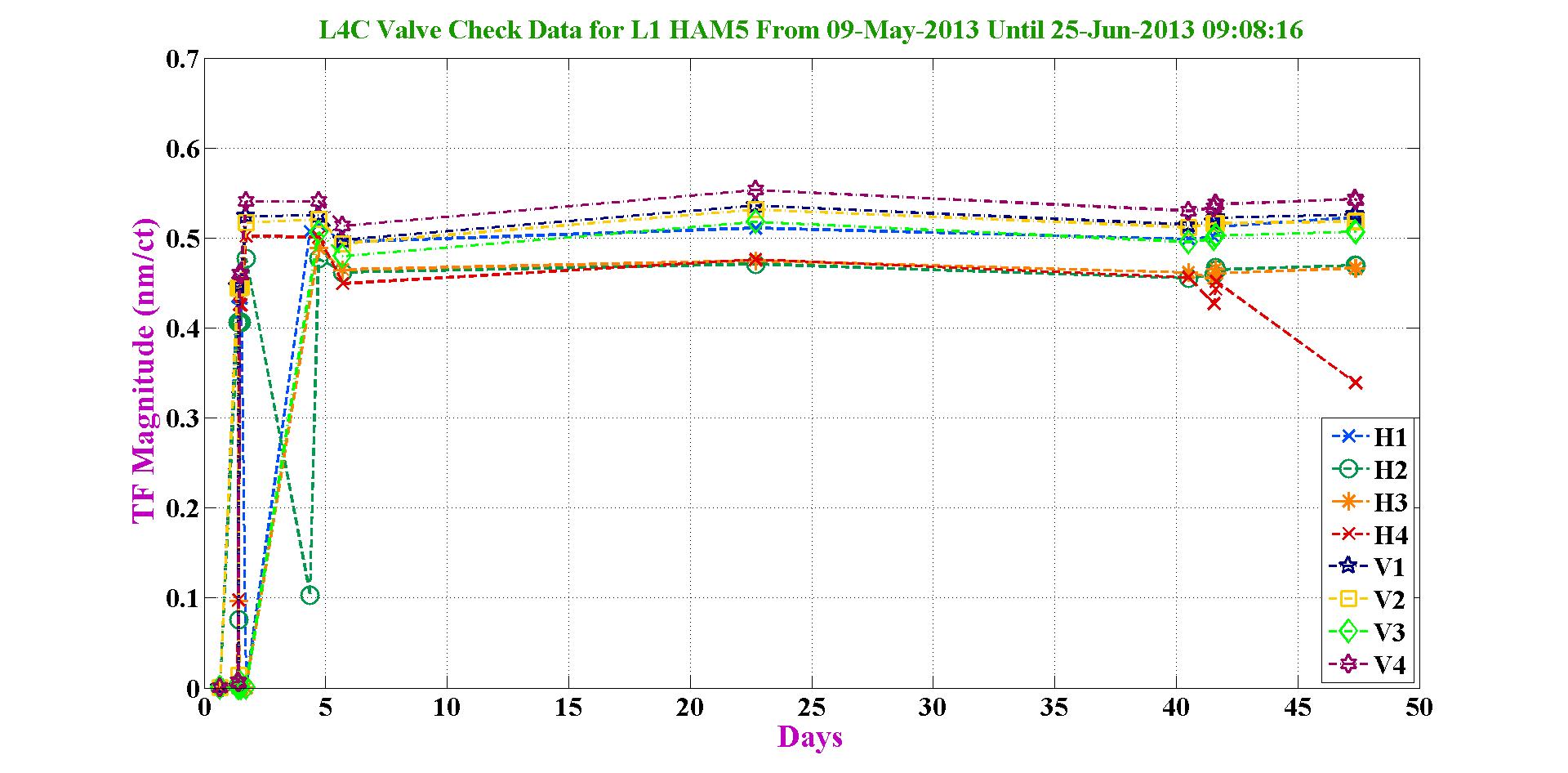


Figure 21: Valve check evolution plot

***Note:*** On this last figure, we can see that H4 valve is faulty. This is confirmed by the Local to local measurements. The valve will be replaced when time permits and the failed tests will be redone.

**Acceptance criteria:**

* **Test result: Passed: Failed: X . Waived: . .**

## Local-to-local measurements

**Data files in SVN at:**

*/SeiSVN/seismic/HEPI/L1/HAM5/Data/Transfer\_Functions/Measurements/Undamped/*

* *L1\_HEPI\_HAM5\_0p05\_to\_0p5Hz\_20130619-164421.mat*
* *L1\_HEPI\_HAM5\_0p5\_to\_2Hz\_20130616-184207.mat*
* *L1\_HEPI\_HAM5\_2\_to\_20Hz\_20130619-015047.mat*
* *L1\_HEPI\_HAM5\_20\_to\_100Hz\_20130619-043806.mat*
* *L1\_HEPI\_HAM5\_100\_to\_250Hz\_20130620-063300.mat*

**Data collection script files:**

*/SeiSVN/seismic/HEPI/Common//Transfer\_Function\_Scripts/*

* *Run\_TF\_L2L\_10mHz\_100mHz.m*
* *Run\_TF\_L2L\_100mHz\_500mHz.m*
* *Run\_TF\_L2L\_500mHz\_5Hz.m*
* *Run\_TF\_L2L\_5Hz\_100Hz.m*
* *Run\_TF\_L2L\_100Hz\_1000Hz.m*

**Scripts files for processing and plotting in SVN at:**

*/SeiSVN/seismic/HEPI/L1/HAM5/Scripts/Control\_Scripts/Version\_5/*

* *Step\_1\_TF\_Loc\_to\_Loc\_L1\_HEPI\_HAM5.m*

**Figures in SVN at:**

*/SeiSVN/seismic/HEPI/L1/HAM5/Data/Figures/Transfer\_Functions/Measurements/Undamped/*

* *L1\_HPI\_HAM5\_TF\_L2L\_Raw\_from\_ACT\_to\_IPS\_2013\_06\_19.fig*
* *L1\_HPI\_HAM5\_TF\_L2L\_Raw\_from\_ACT\_to\_L4C\_2013\_06\_19.fig*

**Storage of measured transfer functions in the SVN at:**

*/SeiSVN/seismic/HEPI/L1/HAM5/Data/Transfer\_functions/ Simulations/Undamped/*

* *L1\_HPI\_HAM5\_TF\_L2L\_Raw\_2013\_06\_19.mat*

The local-to-local transfer functions are presented below.

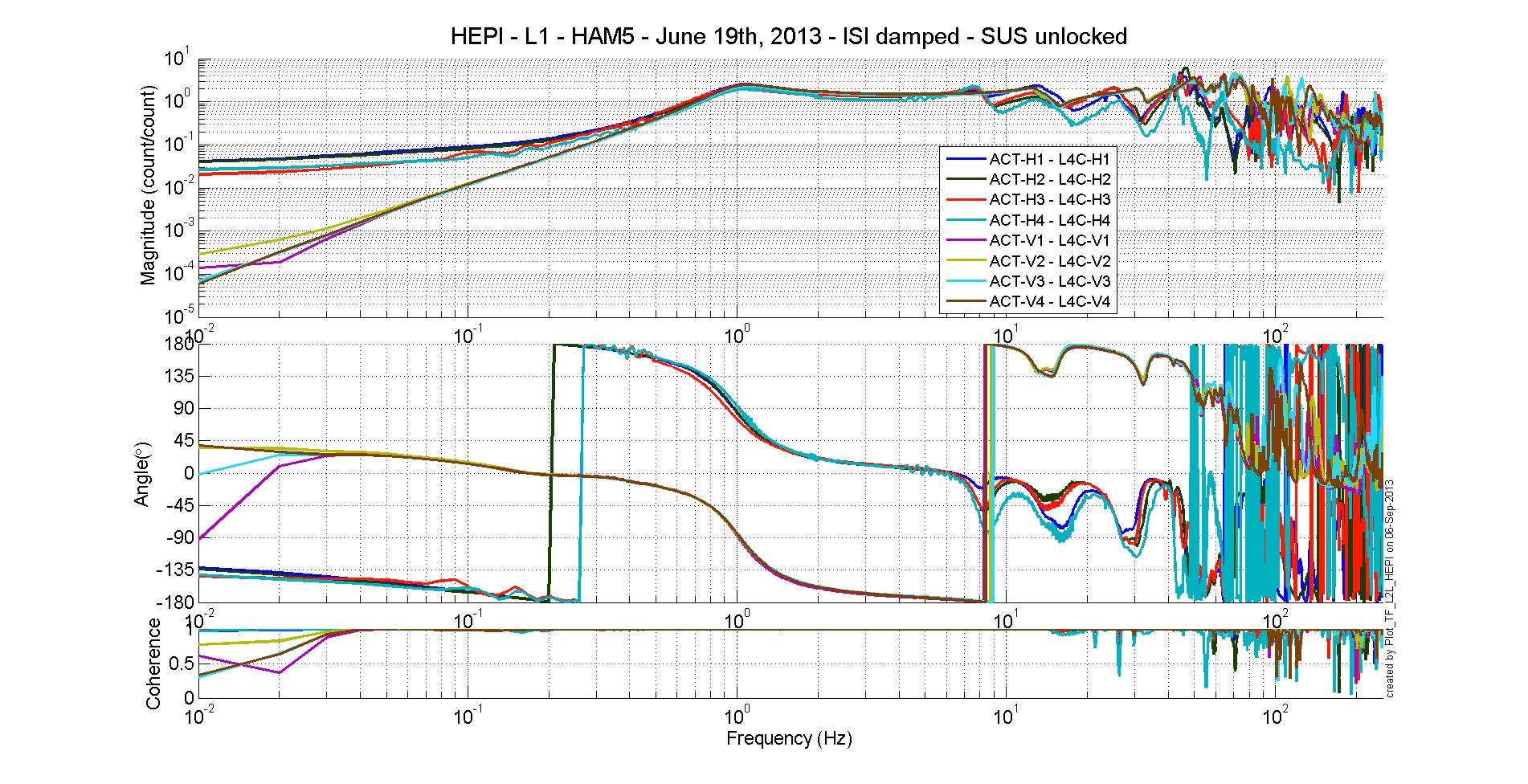


Figure 22:L1 HAM 5 HEPI Act to L4C Transfer Functions

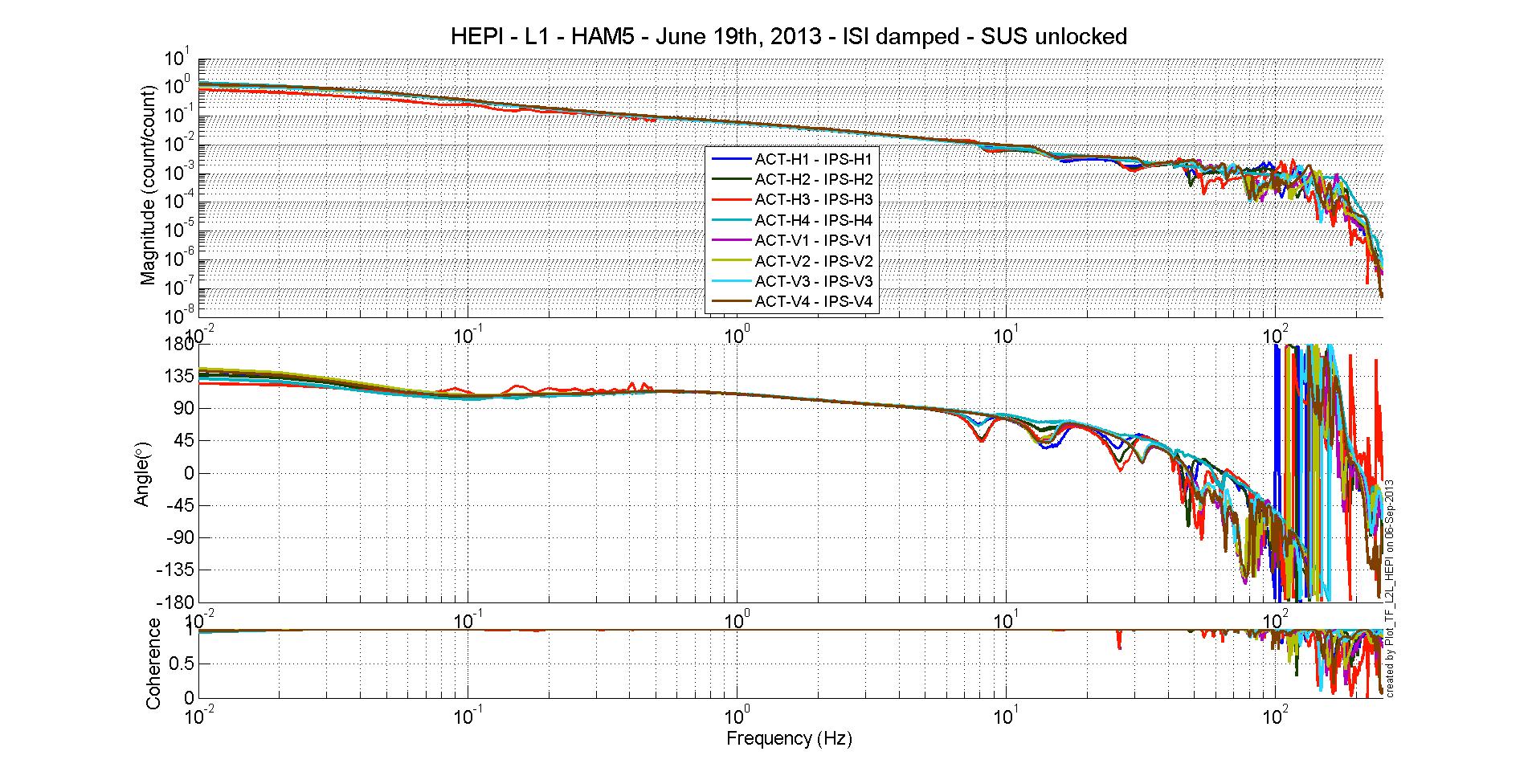


Figure 23: L1 HAM 5 HEPI Act to IPS Transfer Functions



Issues/difficulties/comments regarding this test:

**Acceptance criteria:**

* On IPS, the phase must be 0º at DC
* On geophones, the phase must be 90º at DC
* Identical shape in each corner

**Test result: Passed: X Failed: . Waived: . .**

## Alignment offsets:

Those are the IPS readouts that were recorded with HEPI locked, after alignment work was performed. The opposite of those values is to be installed as offset of the IPS filter banks when the Isolation loops are turned on. This way, HEPI will be operating in its *preferred alignment* state.

|  |  |  |
| --- | --- | --- |
|  | IPS Readouts HEPI Locked | Offset Value |
| H1 |  |  |
| H2 |  |  |
| H3 |  |  |
| H4 |  |  |
| V1 |  |  |
| V2 |  |  |
| V3 |  |  |
| V4 |  |  |

**Acceptance criteria:**

Offsets were recorded.

**Test result: Passed: Failed: . Waived: . .**

# Conclusion

L1 HAM 5 HEPI seems good so far, we still have a few tests to run but should not have any issue with it. Here is a list of the tests that will be done:

* 1.1 Load Cell Assembly: the value will be recorded in this document
* 1.4 Check Stops Gaps: this test will be done when we unlock HEPI on L1 HAM 5
* 1.6 IPS Centering
* 1.7 Sensor ASD
* 1.9 Static Test Local Drive
* 1.10 Linearity Test
* 1.14 Alignment Offsets

Some of the tests have been waived:

* 1.2 Bellows: the bellows are hard to access and tests are hard to proceed. After several discussions and brainstorming sessions, it has been decided not to measure the gaps on HEPI-HAM.
* 1.5 Gaps Check: this test can be waived if step 1.10 Linearity Test/Range of motion in the local basis passes because it means that the system has a full range of motion and is, therefore, free to move
* 1.11 Actuator Plate to Shield gap: this test was not performed because the Range of motion gave good results

So far, we have the 1.3 Boot Location that fails, but the requirements might be a little bit too strict for this test and our results are in the ballpark, the real issue with this HEPI is the H4 faulty actuator valve. This valve will be swapped and all the failed tests will be redone in order to approve this Unit.