*LIGO Laboratory / LIGO Scientific Collaboration*

**LIGO-** E1000325 *LIGO* August 16, 2010

# aLIGO HAM-ISI, Pre integration Test report, Phase 1, LLO Unit #1

Celine Ramet, Michael Vargas, Richard Mittleman, Fabrice Matichard, Vincent Lhuillier

Distribution of this document:
Advanced LIGO Project

This is an internal working note
of the LIGO Laboratory

**California Institute of Technology**
**LIGO Project – MS 18-34**
**1200 E. California Blvd.**
**Pasadena, CA 91125**
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

**Massachusetts Institute of Technology**
**LIGO Project – NW22-295**
**185 Albany St**
**Cambridge, MA 02139**
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

**LIGO Hanford Observatory**
**P.O. Box 1970**
**Mail Stop S9-02**
**Richland WA 99352**
Phone 509-372-8106
Fax 509-372-8137

**LIGO Livingston Observatory**
**P.O. Box 940**
**Livingston, LA 70754**
Phone 225-686-3100
Fax 225-686-7189

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# *Introduction*

This document presents the tests performed to characterize and validate the “HAM-ISI LLO Unit #1”. This unit is the first unit assembled for aLIGO at LLO.

The procedure document used to perform this test is:

- E1000309 - aLIGO HAM-ISI, Pre-Integration Testing Procedure, Phase I (post assembly, before storage)

Other useful information can be found in:

- E1000300 - HAM-ISI LLO test stand: software and electronic check

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# I. Pre-Assembly Testing

- ***Step 1: Position Sensors***

Note: The back panel reads 0.508V/0.001"

| S/N sensor | S/N board | ADE Gap Standoff(mm) | Location on the Jig | Gap Standoff on Jig(mm/in) | Voltage before zeroing | Voltage after zeroing. Prebake | Voltage after zeroing. Post bake |
|---|---|---|---|---|---|---|---|
| 12000 | 12000 | NR | NR | NR | NR | NR | NR |
| 12001 | 12001 | NR | NR | NR | NR | NR | NR |
| 12067 | 12067 | NR | NR | NR | NR | NR | NR |
| 11985 | 11985 | NR | NR | NR | NR | NR | NR |
| 11923 | 11992 | NR | NR | NR | NR | NR | NR |
| 12066 | 12066 | NR | NR | NR | NR | NR | NR |

NR: not recorded

Will be measured for the next units.

**Sensors noise spectra measured before baking:**

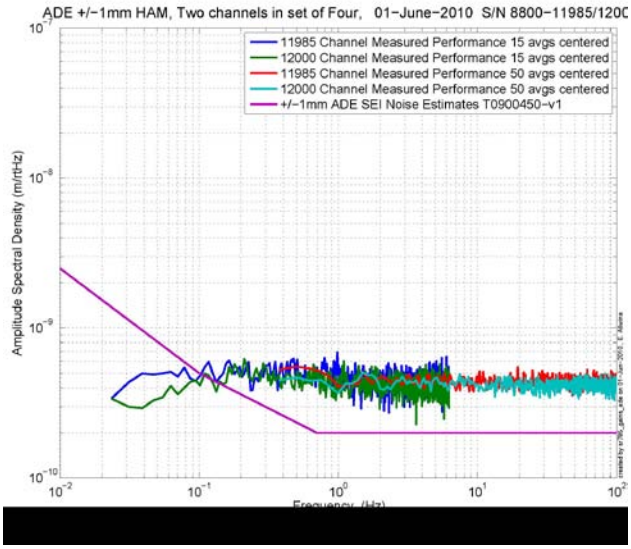


**Figure - H1 and V1 sensor noise**

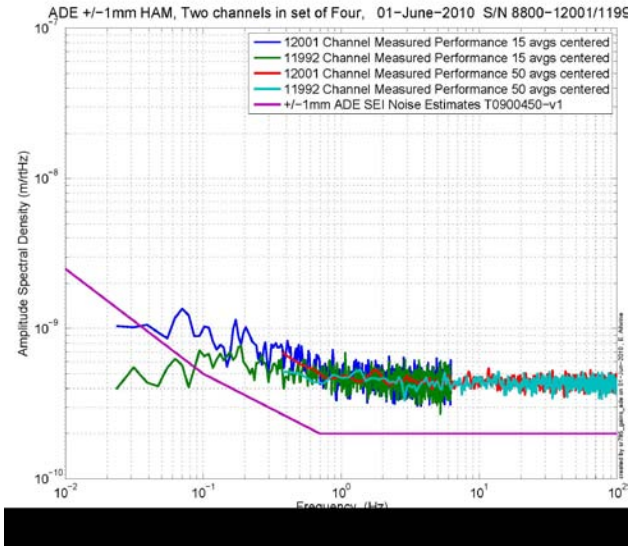


**Figure - H2 and V2 sensor noise**

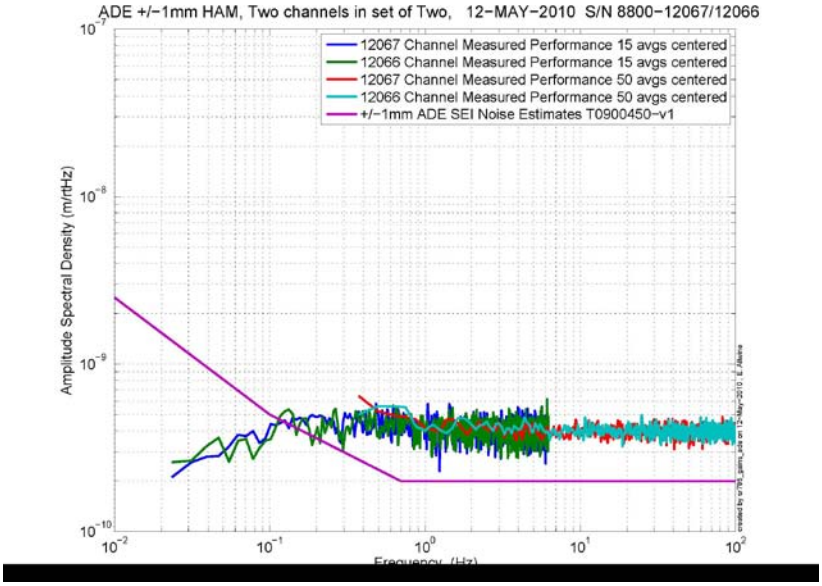


**Figure - H3 and V3 sensor noise**

**Acceptance Criteria:** **To be defined**.

Issues/difficulties/comments regarding this test: Values of sensor gaps and zeroing were nor recorded. Waived for this unit.

**Test result:** **Passed: __X__** **Failed: ___**

- ***Step 2: GS13***

All the data related to GS-13 post podding testing can be found in the SVN at : SeismicSVN\seismic\Common\Data\aLIGO_GS13_TestData\PostMod_TestResults_PDFs.

E1000058 spreadsheet provides the status of each individual GS-13 at LLO site during aLIGO HAM assembly

**Acceptance Criteria:** To be defined.

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 3: Actuators***

Actuator data can be found at: T0900564. Actuator inventory is made at Section II – Step 1.

**Acceptance Criteria:** To be defined.

**Test result:** **Passed: ___** **Failed: ___**

# II. Tests to be performed during assembly

- ***Step 1: Check torques on all bolts***

**Acceptance Criteria:**

- All bolts should trip the wrench, and start moving immediately after. If any bolts in a pattern move before torque is reached, recheck after all bolts are brought to spec.

**Test result:** **Passed: X** **Failed: ___**

- ***Step 2: Check gaps under Support Posts***

**Acceptance Criteria:**

- The test is passed if: a 0.001 inch shim cannot be passed freely through any connection to Stage 0 or between post and gussets. If shim can pass through, loosen all constraining bolts, and then retighten iteratively from the center of the part to the edges. Retest.

**Test result:** **Passed: X** **Failed: ___**

- ***Step 3: Pitchfork/Boxwork flatness before Optical Table install***

**Acceptance Criteria:**

- Shim inserted won't pass between parts.

**Test result:** **Passed: X** **Failed: ___**

- ***Step 4: Blade spring profile***

**Test Results, August 5, 2010:**

| | Base (") | Tip(") | Flatness (mils) |
|---|---|---|---|
| **Spring 1** | 0.5115 | 0.49375 | 17.75 |
| **Spring 2** | 0.502 | 0.48875 | 13.25 |
| **Spring 3** | 0.501 | 0.4875 | 13.5 |

**Acceptance Criteria**

- Blades must be flat within 0.020" inches. To be approved

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 5: Gap checks on actuators***

**Acceptance Criteria**

- Gaps must be within 0.010” of design (i.e. 0.090” and .070” pass, but 0.095” and 0.065” doesn’t).

**Test result:** **Passed: X** **Failed: ___**

- ***Step 6: Check level of Stage 0***

**Acceptance Criteria** To be defined.

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 7: Mass budget***

| Optical Mass (Kg) | Wall Mass (Kg) | Keel Mass (Kg) | Total Mass (Kg) |
|---|---|---|---|
| 325.00 | 164.02 | 90.08 | 579.10 |

**Table - Masses distribution**

The total weight is 579.1Kg.

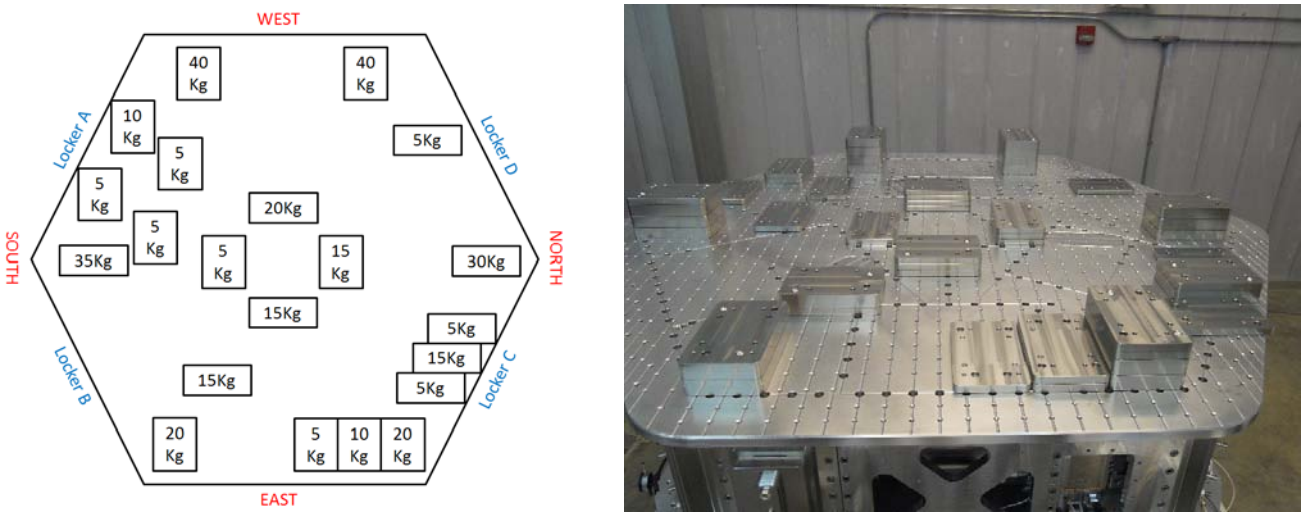


**Figure - Masses distribution**

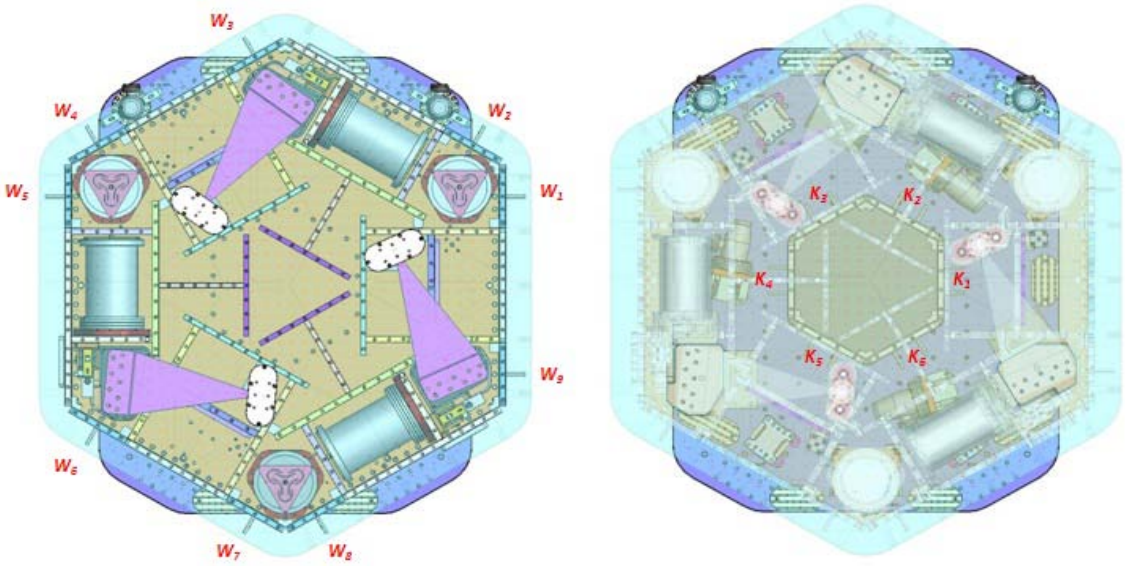


**Figure – Keel Masses and Wall masses location**

| | Mass | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Type | 00 | 01 | 02 | 03 | 04 | 05 | 06 | |
| | Weight | 0.6 | 1.1 | 2.2 | 4.5 | 7.9 | 15.6 | 27.2 | lbs | kgs |
| Location | w1 | | | | 1 | 1 | | 1 | 39.6 | 18.0 |
| | w2 | 0 | 0 | 1 | 1 | | 2 | | 37.9 | 17.2 |
| | w3 | 0 | 1 | 1 | 1 | 2 | 1 | | 39.2 | 17.8 |
| | w4 | | 1 | 1 | 1 | 1 | 2 | 0 | 46.9 | 21.3 |
| | w5 | 0 | 3 | 1 | 1 | 2 | 1 | | 41.4 | 18.8 |
| | w6 | 0 | 1 | 1 | 1 | 0 | 2 | 0 | 39 | 17.7 |
| | w7 | | | | 1 | 1 | | 1 | 39.6 | 18.0 |
| | w8 | 0 | 1 | 1 | 1 | 0 | 2 | | 39 | 17.7 |
| | w9 | 0 | 1 | 1 | 1 | | 2 | 0 | 39 | 17.7 |
| | | 0 | 7 | 6 | 8 | 7 | 10 | 2 | 361.6 | **164.0** |
| Location | k1 | | | | | 1 | | 1 | 35.1 | 15.9 |
| | k2 | 1 | 1 | 1 | | | | 1 | 31.1 | 14.1 |
| | k3 | | | | | 1 | | 1 | 35.1 | 15.9 |
| | k4 | 1 | 1 | 1 | | | | 1 | 31.1 | 14.1 |
| | k5 | | | | | 1 | | 1 | 35.1 | 15.9 |
| | k6 | 1 | 1 | 1 | | | | 1 | 31.1 | 14.1 |
| | | 3 | 3 | 3 | 0 | 3 | 0 | 6 | 198.6 | **90.1** |

**Table – Wall masses and Keel masses distribution**

Locker shim thickness indicated in mils.

| Lockers | Shim thickness (mil) |
|---|---|
| A | |
| B | |
| C | |
| D | |

**Table – Shims Thicness**

**Acceptance Criteria**

- The total weight must be Kg +/- Kg

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 8: Lockers adjustment***

| D.I at Lockers | Dial indicators V | Dial indicators H |
|---|---|---|
| A | 0.5 | 1 |
| B | 0 | -1 |
| C | 1 | 1 |
| D | 1 | -1.5 |

**Table – Dial indicators read-out**

Issues/difficulties encountered during this test : This test has been performed three times due to important variation of the plant with time. On initial measurements, measured variations between locked and unlocked configuration were around 3 mils on horizontal D.I and 1 mil on vertical D.I. We saw that one actuator cable was touching stage 1. After clamping the cable properly to stage 0 to avoid contact with stage 1, variations between locked and unlocked configurations fall to 1 mil on vertical dial indicators and 1.5 mil on horizontal dial indicators (table above).

**Acceptance Criteria**

- Vertical and horizontal displacement near the lockers must be lower than 2 mils

**Test result:** **Passed: ___** **Failed: ___**

# III. Tests to be performed after assembly

- ***Step 1 - Actuators Inventory***

| Actuator | Actuator S/N |
|---|---|
| **H1** | |
| **H2** | |
| **H3** | |
| **V1** | 147 |
| **V2** | 74 |
| **V3** | 95 |

**Table - Actuators' inventory**

Issues/difficulties/comments regarding this test: Horizontal actuators S/N missing

**Acceptance Criteria:** all S/N must be recorded.

**Test result:** **Passed: ___** **Failed: _X_**

- ***Step 2 - Sensors Inventory***

| Sensor | CPS S/N | Mount S/N | ADE board serial # |
|---|---|---|---|
| **H1** | 12000 | | 8800-12000 |
| **H2** | 12001 | | 8800-12001 |
| **H3** | 12067 | | 8800-12067 |
| **V1** | 11985 | | 8800-11985 |
| **V2** | 11992 | | 8800-11992 |
| **V3** | 12066 | | 8800-12066 |

**Table - Capacitive position sensors' inventory**

| Geophones GS13 | Serial Number | POD |
|---|---|---|
| **H1** | 785 | 57 |
| **H2** | 789 | 47 |
| **H3** | 797 | 52 |
| **V1** | 682 | 6 |
| **V2** | 691 | 4 |
| **V3** | 707 | 1 |

**Table - Geophones' inventory**

Issues/difficulties/comments regarding this test:

**Test result:** **Passed: ___** **Failed: _X_**

- ***Step 3 - Electronics Inventory***

Write down serial number of coil driver, Anti aliasing chassis, Anti image chassis and interface chassis used for this test are listed below:

| Hardware | LIGO reference | S/N |
|---|---|---|
| **Coil driver** | D0902744 | S1000317 |
| | | S1000316 |
| **Anti Image filter** | D070081 | S1000251 |
| **Anti aliasing filter** | D1000269 | S1000244 |
| | | S1000298 |
| **Interface chassis** | D1000067 | S1000311 |
| | | S1000312 |
| | | S1000314 |

**Table - Inventory electronics**

Issues/difficulties/comments regarding this test:

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 4 - Set up sensors gap***

| Table locked | ADE boxes on | | ADE boxes on/off | |
|---|---|---|---|---|
| **Sensors** | **Offset (Mean)** | **Std deviation** | **Offset (Mean)** | **Std deviation** |
| **H1** | 180 | 3.7 | 181 | 3.4 |
| **H2** | 155 | 4.8 | -155 | 3.9 |
| **H3** | -28 | 3.7 | | |
| **V1** | -329 | 3.1 | -329 | 3.2 |
| **V2** | -390 | 4.1 | -391 | 4.2 |
| **V3** | 144 | 2.8 | | |

**Table - Set-up sensors gap**

Issues/difficulties/comments regarding this test: HAM-ISI – LLO unit#1 uses synchronized satellite boxes

**Acceptance criteria:**

- All mean values must be lower than 400 cts (a bit less than .0005”).
- All standard deviations below 5 counts.

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 5 - Measure the Sensor gap***

| Sensors | Gap measured on the Jig | Gap measured on the table | % of change | Offset sensors (counts) |
|---|---|---|---|---|
| **H1** | | 0.085" | | 106 |
| **H2** | | 0.08" | | -298 |
| **H3** | | 0.085" | | 373 |
| **V1** | | 0.085" | | 441 |
| **V2** | | 0.085" | | 165 |
| **V3** | | 0.085" | | -252 |

**Table - Sensors gap**

Issues/difficulties/comments regarding this test: No information of gaps measured on the Jig

**Acceptance criteria:**

- Change of gaps lower than 2% (reference is the gap measured on the Jig)

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 6 - Check Sensor gaps after the platform release***

| | Table locked | | Table unlocked | |
|---|---|---|---|---|
| **Sensors** | **Offset (Mean)** | **Std deviation** | **Offset (Mean)** | **Diff unlocked - locked** |
| **H1** | -63 | 4.0 | 1658 | 1721 |
| **H2** | -19 | 4.0 | 1408 | 1427 |
| **H3** | 158 | 3.0 | 1849 | 1691 |
| **V1** | -278 | 3.0 | -1028 | -750 |
| **V2** | -379 | 4.0 | -771 | -392 |
| **V3** | 129 | 3.0 | -505 | -634 |

**Table – Sensor gaps after platform release**

Issues/difficulties/comments regarding this test:

**Acceptance criteria:**

- Absolute values of the difference between the unlocked and the locked table must be below:
  - 1600 cts for horizontal sensors (~0.002")
  - 1600 cts for vertical sensors (~0.002")
- Considering the acceptance criteria of step 4, all mean values must be lower than
  - 2000 cts for horizontal sensors (~0.0025")
  - 2000 cts for vertical sensors (~0.0025")

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 7 - Check range of motion (hand pushing)***
  - ***Step 7.1 – Test Nº1***

| | CPS read out | | Calculated after calibration | |
|---|---|---|---|---|
| **Sensors** | **UP (Counts)** | **Down (Counts)** | **UP (mil)** | **Down (mil)** |
| **V1** | 20634 | -19404 | 24.6 | -23.1 |
| **V2** | 20165 | -20185 | 24.0 | -24.0 |
| **V3** | 20482 | -18891 | 24.4 | -22.5 |

| | CPS read out | | Calculated after calibration | |
|---|---|---|---|---|
| **Sensors** | **CW(-RZ)** | **CCW (+RZ)** | **CW (mil)** | **CCW (mil)** |
| **H1** | 23340 | -22750 | 27.8 | -27.1 |
| **H2** | 20600 | -20750 | 24.5 | -24.7 |
| **H3** | 21000 | 20940 | 25.0 | 24.9 |

**Table - Optic table range of motion**

Issues/difficulties/comments regarding this test: the results indicate that all displacement sensor signals have the same sign all the way through the read chain.

  - ***Step 7.2 – Test Nº2***

**Displacement sensors and actuator gap check:**

| | Push in positive direction | Push in negative direction | Railing | Actuator Gap Check |
|---|---|---|---|---|
| **H1** | 23973 | -24453 | | **X** |
| **H2** | 23636 | -24425 | | **X** |
| **H3** | 24861 | -24552 | | **X** |
| **V1** | 19800 | -17583 | | **X** |
| **V2** | 32767 | -32768 | **X** | **X** |
| **V3** | 18664 | -19104 | | **X** |

**Table - Sensor and Actuator gap check**

**Acceptance criteria:**

- The vertical sensor readout be positive when the optic table is pushed in the +Z direction
- The horizontal sensor readout be negative when the optic table is pushed in the +RZ direction
- **Step 7.1**
  - Absolutes value of all estimated motions must be higher than 16000counts (~0.020")
- **Step 7.2**
  - No contact point on sensors
  - Absolute value of sensor read out must be higher than 16000counts (~0.020")
  - No contact point on actuators

**Test result:** **Passed: ___** **Failed: ___ .**

- ***Step 8 - Capacitive position sensor Power Spectrum***

**Data files in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/DTT_Powerspectrum_Undamped
- Power_spectrum_table_locked_ADE_Sync_072910_N2.xml
- Power_spectrum_table_unlocked_ADE_Sync_072910.xml
- Power_spectrum_table_locked_ADE_Sync_072910_N2.txt
- Power_spectrum_table_unlocked_ADE_Sync_072910.txt

**Scripts files for processing and plotting in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/DTT_Powerspectrum_Undamped
- PSD_GS13_lock_unlock_HAM_ISI_LLO_unit_1_2010_08_05.m

**Figures in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Figures/Powerspectrum_GS13_CPS
- Calibrated_CPS_Powerspectrum_when_Locked_Unlocked.fig

**CPS calibration:**
The CPS power spectrums are calibrated by using a sensitivity of 30.2nm/count.

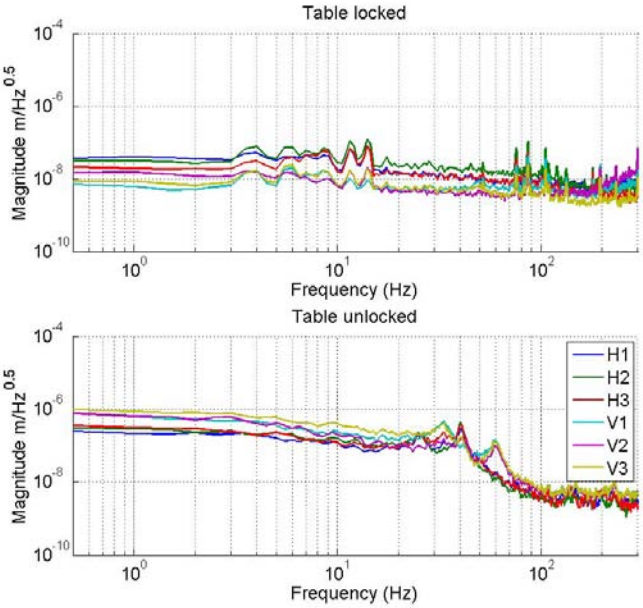


**Figure - Calibrated CPS power spectrum**

**Acceptance criteria:**
- No cross talk (peaks at low frequencies + harmonics on measurements)
- Magnitude of power spectrums must be
  - Less than 5e-10m/√Hz at 0.1Hz
  - Less than 5e-10m/√Hz at 1Hz
  - Less than 5e-10m/√Hz at 10Hz

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 9 - GS13 power spectrum***

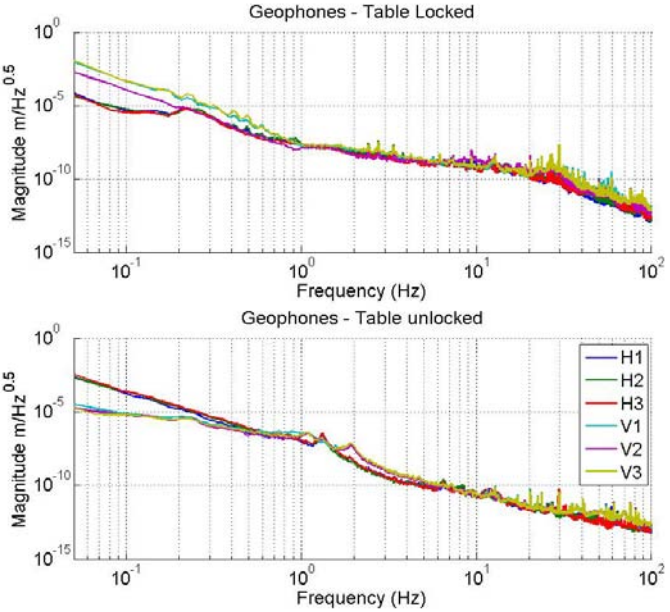


**Figure – Power spectrum Calibrated GS13 with mass at corner**

The figure below presents the GS13 powerspectrum when the table is unlocked and loaded with a 20Kg mass at one of its corner.

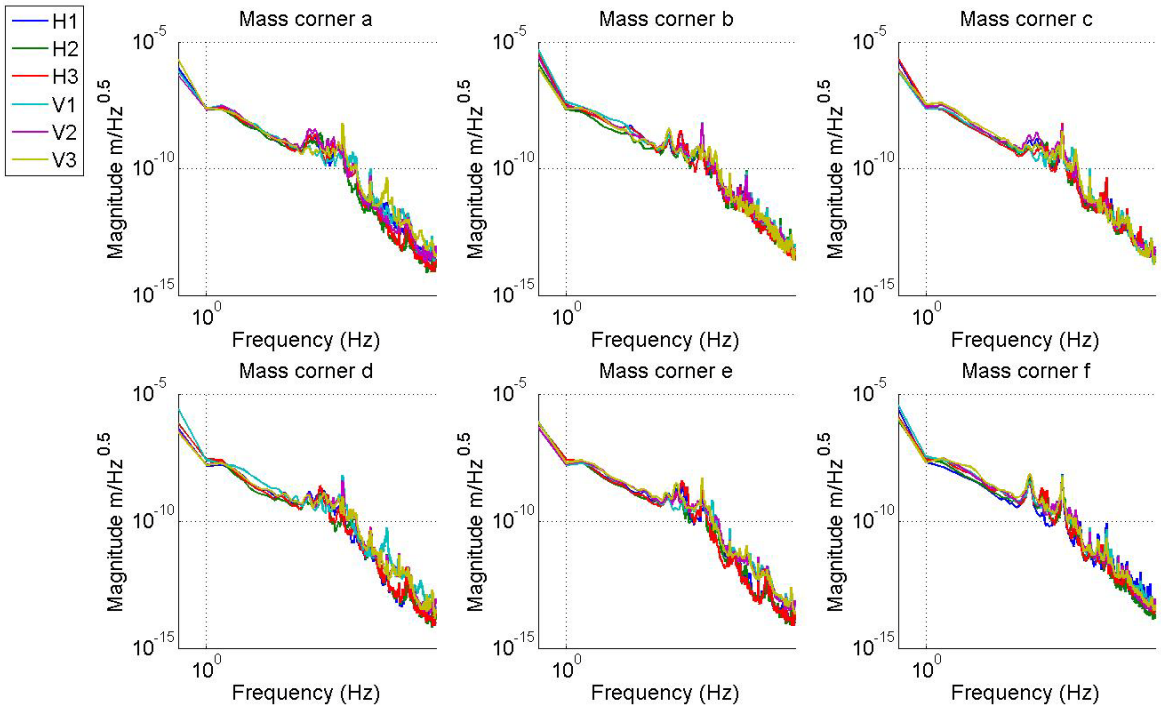


**Figure – Power spectrum Calibrated GS13 with mass at corner**

**Data files in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/DTT_Powerspectrum_Undamped

- Power_spectrum_table_locked_ADE_Sync_072910_N2.xml
- Power_spectrum_table_unlocked_ADE_Sync_072910.xml
- Power_spectrum_table_locked_ADE_Sync_072910_N2.txt
- Power_spectrum_table_unlocked_ADE_Sync_072910.txt
- Gs13_test_corner_a_loaded_072910.txt / Gs13_test_corner_a_loaded_072910.xml
- Gs13_test_corner_b_loaded_072910.txt / Gs13_test_corner_b_loaded_072910.xml
- Gs13_test_corner_c_loaded_072910.txt / Gs13_test_corner_c_loaded_072910.xml
- Gs13_test_corner_d_loaded_072910.txt / Gs13_test_corner_d_loaded_072910.xml
- Gs13_test_corner_e_loaded_072910.txt / Gs13_test_corner_e_loaded_072910.xml
- Gs13_test_corner_f_loaded_072910.txt / Gs13_test_corner_f_loaded_072910.xml

**Scripts files for processing and plotting in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/DTT_Powerspectrum_Undamped

- PSD_GS13_lock_unlock_HAM_ISI_LLO_unit_1_2010_08_05.m

**Figures in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Figures/Powerspectrum_GS13_CPS

- Calibrated_Geophones_Powerspectrum_when_table_locked_Unlocked.fig
- Calibrated_Geophones_Powerspectrum_with_20Kg_mass_at_one corner.fig

**Acceptance criteria:**

- Table locked
  - Less than xx at 0.1Hz
  - Less than xx at 1Hz
  - Less than xx at 10Hz
- Table unlocked (no tilt)
  - Less than xx at 0.1Hz
  - Less than xx at 1Hz
  - Less than xx at 10Hz
- Table unlocked (tilt Rx & Ry)
  - Less than xx at 0.1Hz
  - Less than xx at 1Hz
  - Less than xx at 10Hz

**Test result:** **Passed:** ___ **Failed:** _X_

- ***Step 10 - Coil Driver, cabling and resistance check***

| Actuator | V1 | | H1 | | V2 | |
|---|---|---|---|---|---|---|
| Coil driver | S1000316 – Coarse 1 OUT | | S1000316 – Fine 1 OUT | | S1000317 – Fine 2 OUT | |
| Anti image pin # | 1 | | 2 | | 3 | |
| Cable # | 28 | | 25 | | 30 | |
| Resistance (Ohm) | P1 - P2 | P2 - P3 | P1 - P2 | P2 - P3 | P1 - P2 | P2 - P3 |
| | 6.4 | O.L (infinity) | 6.4 | O.L (infinity) | 6.3 | O.L (infinity) |
| MEDM offset (1000 counts) | Volt out: P2 (-) ; P1&P3 (+) | | Volt out: P2 (-) ; P1&P3 (+) | | Volt out: P2 (-) ; P1&P3 (+) | |
| | | | | | | |

| Actuator | H2 | | V3 | | H3 | |
|---|---|---|---|---|---|---|
| Coil driver | S1000317 – Coarse 2 OUT | | S1000317 – Coarse 1 OUT | | S1000317 – Fine 1 OUT | |
| Anti image pin # | 4 | | 5 | | 6 | |
| Cable # | 29 | | 26 | | 27 | |
| Resistance (Ohm) | P1 - P2 | P2 - P3 | P1 - P2 | P2 - P3 | P1 - P2 | P2 - P3 |
| | 6.3 | O.L (infinity) | 6.3 | O.L (infinity) | 6.4 | O.L (infinity) |
| MEDM offset (1000 counts) | Volt out: P2 (-) ; P1&P3 (+) | | Volt out: P2 (-) ; P1&P3 (+) | | Volt out: P2 (-) ; P1&P3 (+) | |
| | | | | | | |

**Table - Actuators resistance check**

Issues/difficulties/comments regarding this test: During testing, we had to check anti-image pins due to a no actuator drive.

**Acceptance criteria:**

- The measured resistance between the middle pin and one side pin must be 6.5 +/-1 ohms
- Actuator neutral pins must be connected on pin #1 (left side pin of the plug)
- Actuator drive pins must be connected on pin #2 (middle pin of the plug)
- Actuator ground shield pins must be connected on pin #3 (right pin of the plug)
- All LEDs on the coil driver front panel must be green

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 11 - Actuators Sign and range of motion (Local drive)***

  - ***Step 11.1 - Actuators sign***

**Acceptance criteria:** A positive offset drive on one actuator must give positive sensor readout on the collocated sensor. Signs will also be tested when measuring local to local transfer functions.

**Test result:** **Passed: X** **Failed: ___**

- *Step 11.2 - Range of motion - Local drive*

| | Positive and negative offset Drive(+/-30000 counts) | | | | | |
|---|---|---|---|---|---|---|
| | V1 | V2 | V3 | H1 | H2 | H3 |
| V1 readout (counts) | | | | X | X | X |
| V2 readout (counts) | | | | X | X | X |
| V3 readout (counts) | | | | X | X | X |
| H1 readout (counts) | X | X | X | | | |
| H2 readout (counts) | X | X | X | | | |
| H3 readout (counts) | X | X | X | | | |

**Table - Range of motion - Local drive**

Issues/difficulties/comments regarding this test: No time to perform that test

**Acceptance criteria:**

- Main couplings read out must be at least 16000 counts (~0.002")
- Signs of actuators drive and sensors read out have to be the same

**Test result:** **Passed: ___** **Failed: _X__**

- *Step 12 - Vertical Sensor Calibration*

| D.I at Lockers | D.I readout with for a negative drive | D.I readout without any drive | D.I readout with for a positive drive | |
|---|---|---|---|---|
| A | -19 | 0 | 20 | |
| B | -19 | 0 | 19 | |
| C | -18.5 | 0 | 19 | |
| D | -18 | 0 | 19 | |
| Average | -18.625 | 0 | 19.3 | 37.9 |

| Sensors | Read out (Counts) | Readout (Counts) | Readout (Counts) | Difference (Counts) |
|---|---|---|---|---|
| V1 | -16223 | -500 | 14749 | 30972 |
| V2 | -16125 | -8 | 15987 | 32112 |
| V3 | -17814 | -1625 | 14525 | 32339 |
| | | | Average | 31808 |

**Table - Calibration of capacitive position sensors**

**Vertical sensitivity:** 31808/37.9 = 839.8 count/mil

or 839.8 count/mil * 1/1638 V/count = 0.513V/mil

or 25400nm/mil * 1/839.8 mil/count = 30.24 nm/count

**Difference with Nominal sensitivity = (839.8-840)/840=-0.02%**

Issues/difficulties/comments regarding this test:

**Acceptance criteria:** Deviation from nominal value < 2%. Nominal value is 840 count/mil.

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 13 - Vertical Spring Constant***

| Sensors | Mean diff counts | Mean diff m | K (N/m) |
|---|---|---|---|
| **V1** | 7800.25 | 2.36E-04 | 8.30E+04 |
| **V2** | 7711.5 | 2.33E-04 | 8.40E+04 |
| **V3** | 7881.5 | 2.38E-04 | 8.22E+04 |
| | | **Average (N/m)** | **2.49E+05** |

**Table - Vertical spring constant**

The measured vertical stiffness is 2.491e5N/m. The nominal vertical spring constant is 2.428e5N/m. The measured error on the vertical stiffness is 2.62%.

Issues/difficulties/comments regarding this test:

**Acceptance criteria:**

- Spring constant is within +/- 10/-1% of 2.41e4 N/m (HPD FEA Results).

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 14 - Static Testing (Tests in the local basis)***

| Actuators (1000 counts) | Sensors (counts) | | | | | |
|---|---|---|---|---|---|---|
| | **H1** | **H2** | **H3** | **V1** | **V2** | **V3** |
| **H1** | 2019.5 | 1277.5 | 1239 | -1 | 21.5 | -46.5 |
| **H2** | 1264.5 | 2031.5 | 1238 | 2 | 12.5 | -13.5 |
| **H3** | 1235.5 | 1238.5 | 1958 | 21 | 5.5 | -0.5 |
| **V1** | 230 | 210 | -337 | 1411 | -35 | -579 |
| **V2** | -327 | 196 | 177 | -589 | 1371 | 26 |
| **V3** | 154 | -374 | 192 | -68 | 813 | 1443 |

**Main coupling**
**Important cross coupling**

**Table - Main and cross coupling**

Issues/difficulties/comments regarding this test:

**Acceptance criteria:**

- **Vertical**
  For a +1000 count offset drive on vertical actuators
  - Collocated sensors must be 1400 counts +/- 10%
- **Horizontal**
  For a +1000 count offset drive on horizontal actuators
  - Collocated sensors must be 2000 counts +/- 10%
  - Non-collocated horizontal sensors must be 1250 counts +/-10%

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 15 - Linearity test (might not be necessary)***

| Actuators (counts) | Sensors (counts) | | | | | |
|---|---|---|---|---|---|---|
| | V1/V1 | V2/V2 | V3/V3 | H1/H1 | H2/H2 | H3/H3 |
| -7000 | | | | | | |
| -3000 | | | | | | |
| -1000 | | | | | | |
| -300 | | | | | | |
| 0 | | | | | | |
| 300 | | | | | | |
| 1000 | | | | | | |
| 3000 | | | | | | |
| 7000 | | | | | | |

**Table - Linearity test of the triplet Actuators – HAM-ISI – Sensors**

| | Slope | Offset |
|---|---|---|
| H1 | | |
| H2 | | |
| H3 | | |
| V1 | | |
| V2 | | |
| V3 | | |

**Table - Slopes and offset of the triplet Actuators - HAM-ISI - Sensors**

Linearity tests plots

Add figure

**Figure - Horizontal actuators x HAM-ISI x sensors**

Add figure

**Figure - Vertical actuators x HAM-ISI x sensors**

Issues/difficulties/comments regarding this test: No time to perform that test

**Acceptance criteria:**

- Horizontal and vertical slopes of the triplet actuators x HAM-ISI x sensors: Average slope +/- 3%.

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 16 - Tests in the general coordinate basis***

| 1000 counts Drive | X Drive | Y Drive | Z Drive | Rx Drive | Ry Drive | Rz Drive |
|---|---|---|---|---|---|---|
| **H1** | 265 | -459 | 12 | -447 | -266 | -1996 |
| **H2** | 243 | 410 | -7 | 454 | -265 | -1988 |
| **H3** | -513 | -9 | 11 | -5 | 534 | -1961 |
| **V1** | 12 | 17 | 267 | 2943 | -1638 | 27 |
| **V2** | 1 | 10 | 271 | 1706 | 423 | 28 |
| **V3** | 21 | 9 | 290 | -1220 | 1287 | 22 |
| **Direction read out** | **-512** | **-514** | **-230** | **-2595** | **-2582** | **-2514** |

**Table - Tests in the general coordinate basis**

Issues/difficulties/comments regarding this test: CPS Modal readout read negative when drive a positive offset. Actuator matrix signs is good (comparison with reference table). For example, a positive drive on Z gives a positive readout on vertical sensors (local basis) but a negative readout in the "reconstructed Cartesian basis sensors". Consequently sign of the **CONT2ACT** matrix is right and sign of the **DISP2CEN** matrix is wrong. Cartesian to Cartesian transfer functions (step 17) also show the sign issue on **DISP2CEN** matrix.

**DISP2CEN** is (the bad one – Used for this test)

| | X | Y | Z | RX | RY | RZ |
|---|---|---|---|---|---|---|
| **H1** | -0.333 | 0.577 | 0 | 0 | 0 | 0.431 |
| **H2** | -0.333 | -0.577 | 0 | 0 | 0 | 0.431 |
| **H3** | 0.667 | 0 | 0 | 0 | 0 | 0.431 |
| **V1** | 0 | 0 | -0.333 | 0 | 0.937 | 0 |
| **V2** | 0 | 0 | -0.333 | -0.812 | -0.469 | 0 |
| **V3** | 0 | 0 | -0.333 | 0.812 | -0.469 | 0 |

with Cartesian_vector = **DISP2CEN** x Local_vector

For the next unit, **DISP2CEN** matrix sign is modified such that a physical displacement in the positive direction gives a positive readout on "Cartesian sensors".

**DISP2CEN** has been corrected for the next unit. New **DISP2CEN** is

| | H1 | H2 | H3 | V1 | V2 | V3 |
|---|---|---|---|---|---|---|
| **X** | 0.333 | 0.333 | -0.667 | -0.194 | 0.049 | 0.145 |
| **Y** | -0.577 | 0.577 | 0 | 0.056 | -0.196 | 0.140 |
| **Z** | 0 | 0 | 0 | 0.333 | 0.333 | 0.333 |
| **RX** | 0 | 0 | 0 | -0.273 | 0.961 | -0.688 |
| **RY** | 0 | 0 | 0 | -0.952 | 0.240 | 0.712 |
| **RZ** | -0.422 | -0.422 | -0.422 | 0 | 0 | 0 |

**Acceptance criteria:**

For a positive drive in the Cartesian basis:

- Local sensor readout must have the same sign that the reference table (**CONT2ACT check**)
- Cartesian sensors read out must be positive (**DISP2CEN check**) in the drive direction

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 17 - Frequency response***
  - ***Step 17.1 - Local to local measurements***

Local to local transfer functions have been measured with 90 repetitions.

**Data files in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/Local_to_local
- Data_L2L_50mHz_500mHz_20100802-221530.mat
- Data_L2L_500mHz_5Hz_20100805-104653.mat
- Data_L2L_5_200Hz_20100731-184659.mat
- Data_L2L_200_800Hz_20100731-171336.mat

**Data collection script files:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Data_Collection
- Run_L2L_50mHz_500mHz.m
- Run_L2L_500mHz_5Hz.m
- Run_L2L_5mHz_200Hz.m
- Run_L2L_200Hz_800Hz.m

**Scripts files for processing and plotting in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/Local_to_local
- Plot_TF_Local_to_Local_2010_08_05.m

**Figures in SVN at:**
/svncommon/seisvn/seismic/HAMISI/X2/Data/Unit_1/Figures/Transfer_functions/Local_to_Local
- TF_H_CPS.fig
- TF_V_CPS.fig
- TF_H_Geophone.fig
- TF_V_Geophone.fig

**Storage of measured transfer functions in the SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/Local_to_local
- Local_2_Local_LLO_HAM-ISI-Unit_1_2010_08_05.mat

The local to local transfer functions are presented below.

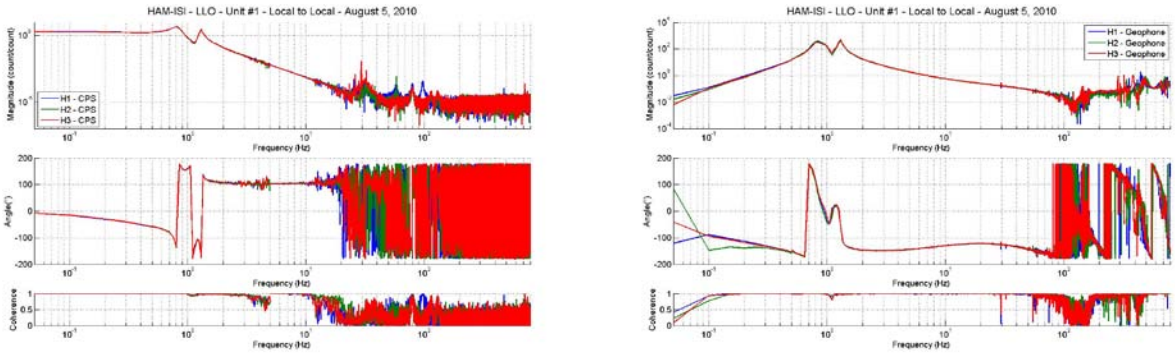


**Figure - Local to Local Measurements**

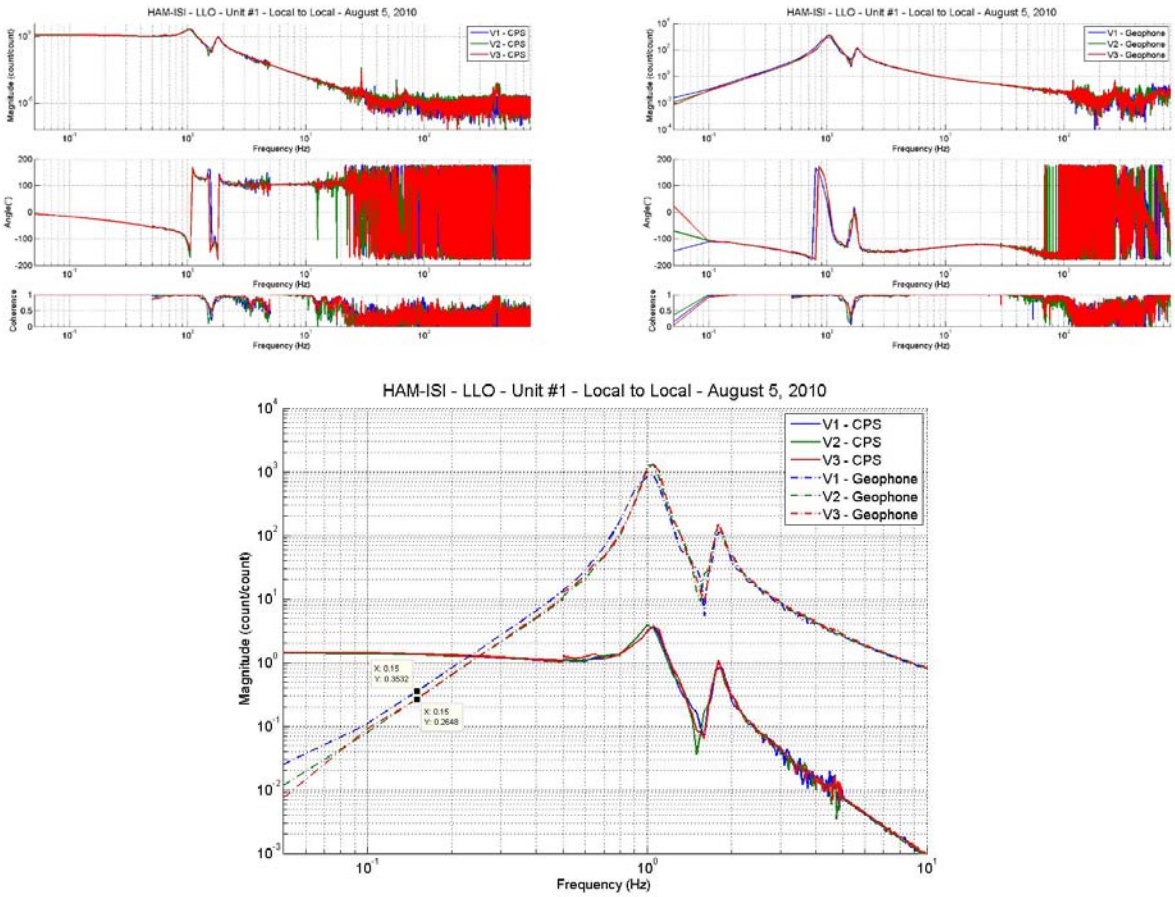


**Figure - Local to Local Measurements – Vertical sensors**

Issues/difficulties/comments regarding this test:

- Even with 90 repetitions, coherence falls to 0.85 at 500mHz – 800mHz (section 2) on vertical sensors (Geophones and CPS).
- Below 1 Hz, GS13 transfer function from actuator V1 to geophone V1 is higher than the other transfer functions (V2, V3) by respectively 25%. The Q at 1 Hz is also lower. These differences are not noticed on the CPS transfer functions.

### o *Step 17.2 - Cartesian to Cartesian measurements*

Cartesian to Cartesian transfer functions have been measured with 90 repetitions.

**Data files in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/Cartesian_to_cartesian

- Data_M2M_50mHz_500mHz_20100805-062421.mat
- Data_M2M_500mHz_5Hz_20100805-031900.mat
- Data_M2M_5_200Hz_20100805-014539.mat
- Data_M2M_200_800Hz_20100805-001218.mat

**Scripts files for processing and plotting in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/Cartesian_to_cartesian

- Plot_TF_cartesian_to_cartesian_2010_08_05.m

**Figures in SVN at:**
/svncommon/seisvn/seismic/HAMISI/X2/Data/Unit_1/Figures/Transfer_functions/
Cartesian_to_cartesian

- TF_X_Y_RZ_CPS.fig
- TF_X_Y_RZ_Geophone.fig
- TF_Z_RX_RY_CPS.fig
- TF_Z_RX_RY_Geophone.fig

**Storage of measured transfer functions in the SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/Cartesian_to_Cartesian

- Cartesian_2_Cartesian_LLO_HAM-ISI-Unit_1_2010_08_05.mat

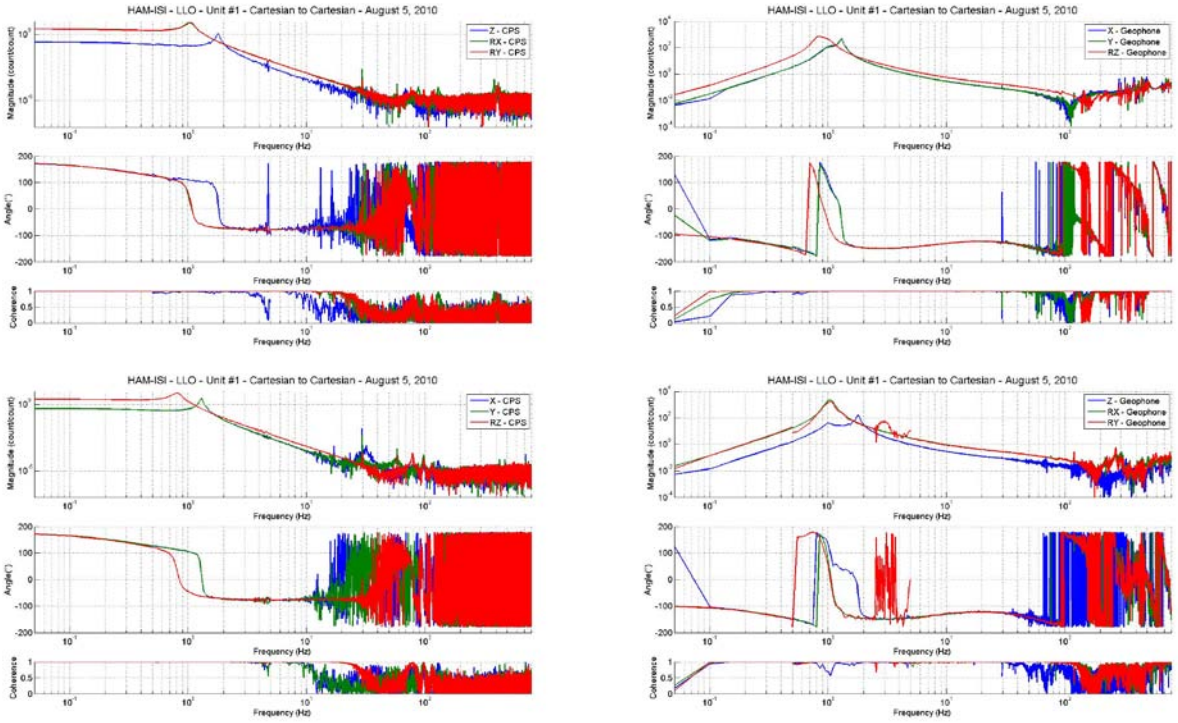


**Figure - Modal to modal measurements**

Issues/difficulties/comments regarding this test: During testing, we overdrove RY creating saturation in section 2 (500mHz to 5Hz). We used a wrong **DISP2CEN** matrix as mentioned at **step 17**.

**Acceptance criteria:**

- Local to local measurement
  - On CPS, the phase must be 0º at DC
  - On Geophones, the phase must be -90º at DC
- Modal to modal measurement
  - On CPS, the phase must be 0º at DC
  - On Geophones, the phase must be -90º at DC

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 18 - Transfer function comparison***
  - ***Step 18.1 - Local to local - Comparison with HAM6***

**Scripts files for processing and plotting in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/Local_to_local

- Plot_TF_local_to_local_2010_08_05.m

**Local to local figures in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Figures/Transfer_functions/Local_to_Local

- TF_H_CPS_vs_HAM6.fig
- TF_V_CPS_vs_HAM6.fig
- TF_H_Geophone_vs_HAM6.fig
- TF_V_Geophone_vs_HAM6.fig

**GS13, Local to local measurement**

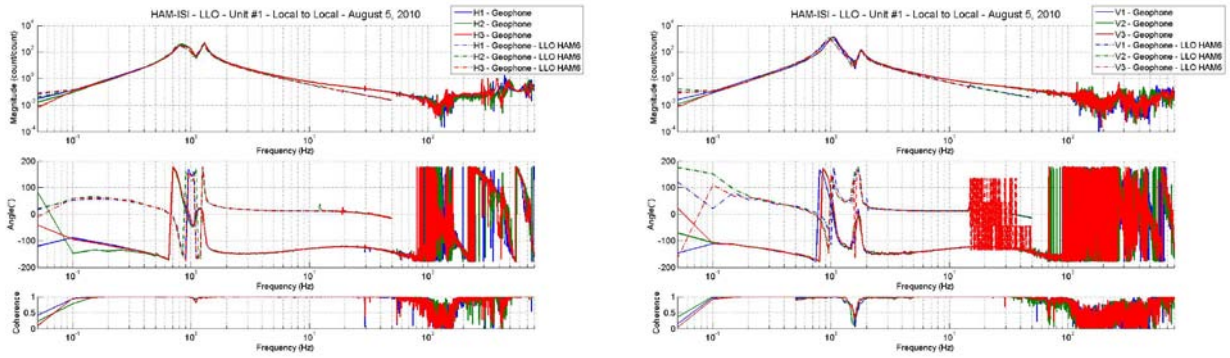


**Figure - Local to local measurements comparison with HAM6 – GS13**

**CPS, Local to local measurement, Undamped**

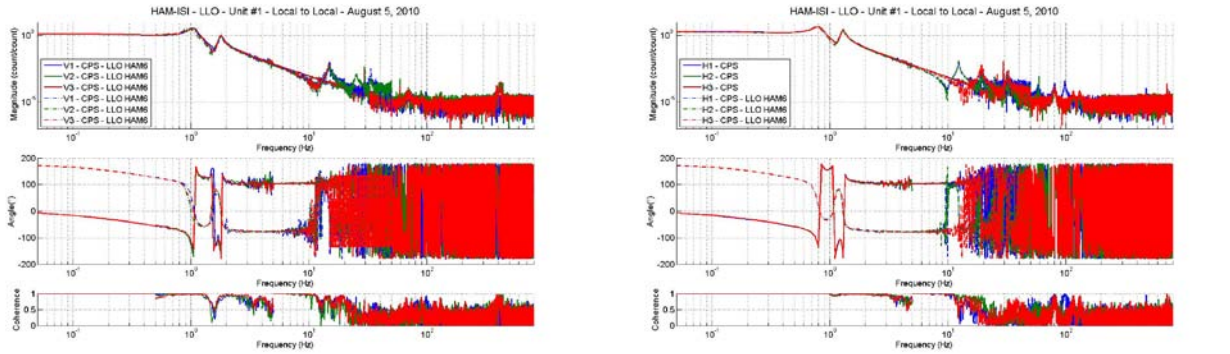


**Figure - Local to local measurements comparison – Position sensors**

**Difference with HAM6:**

- Sign difference on CPS and Geophones.
- Change of the GS13 interface chassis (1 zero at 10Hz and 1 pole at 50Hz)

## o *Step 18.2 - Cartesian toCartesian - Comparison with HAM6*

**Scripts files for processing and plotting in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/Cartesian_to_cartesian

- Plot_TF_cartesian_to_cartesian_2010_08_05.m

**Cartesian to Cartesian figures in SVN at :**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/Cartesian_to_cartesian

- TF_X_Y_RZ_CPS_vs_HAM6.fig
- TF_Z_RX_RY_CPS_vs_HAM6.fig
- TF_X_Y_RZ_Geophone_vs_HAM6.fig
- TF_Z_RX_RY_Geophone_vs_HAM6.fig

**GS13, Cartesian to Cartesian measurement, Undamped**

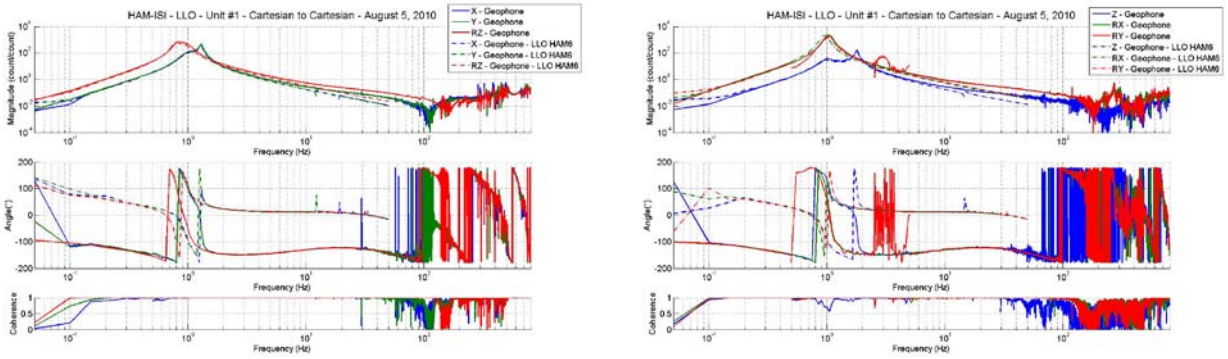


**Figure - Cartesian to Cartesian measurements comparison with HAM6 – GS13**

**CPS, Cartesian to Cartesian measurement, Undamped**

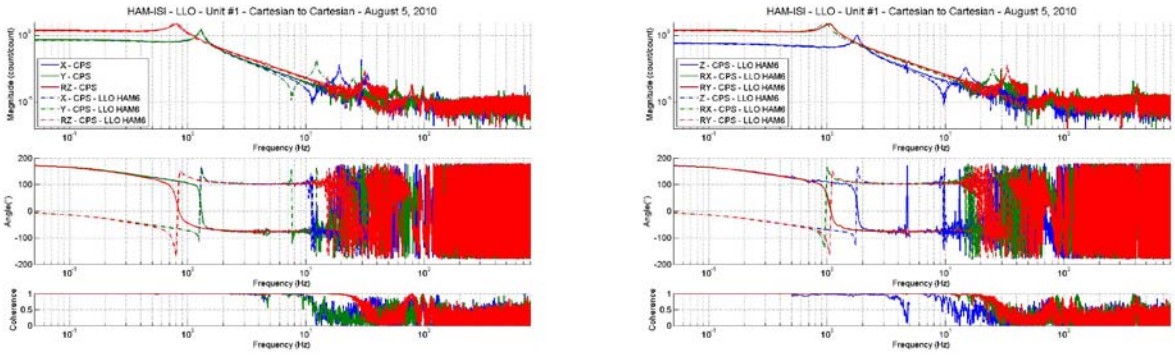


**Figure - Cartesian to Cartesian measurements comparison – Position sensors**

**Difference with HAM6:**

- Resonnance at 1 Hz (RX and RY) is slightly higher than HAM6
- Sign difference on CPS and Geophones
- Change of the GS13 interface chassis (1 zero at 10Hz and 1 pole at 50Hz)

**Acceptance criteria:**

- No difference with the reference transfer functions (SVN)
  - Phase – less than 10º - In Phase – Out of Phase
  - Damping (fit by eye with the reference transfer functions)
  - DC gain
  - Eigen frequencies shift less than 5%

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 19 - Lower Zero Moment Plan***

**Data collection script files:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Data_Collection
- Run_Cart2Cart_10mHz_100mHz.m

**Data files in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/LZMP
- Data_M2M_10mHz_100mHz_20100805-121423.mat

**Scripts files for processing and plotting in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Transfer_functions/LZMP
- LZMP_2010_08_05.m

**Figures in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Figures/Transfer_functions/LZMP
- LZMP.fig

**X & Y offsets:**

| | |
|---|---|
| **X offset (mm)** | **0.16** |
| **Y offset (mm)** | **0.19** |

**Table – Offset of the Lower Zero Moment Plane**

The results from two measurements are presented on the figure below:

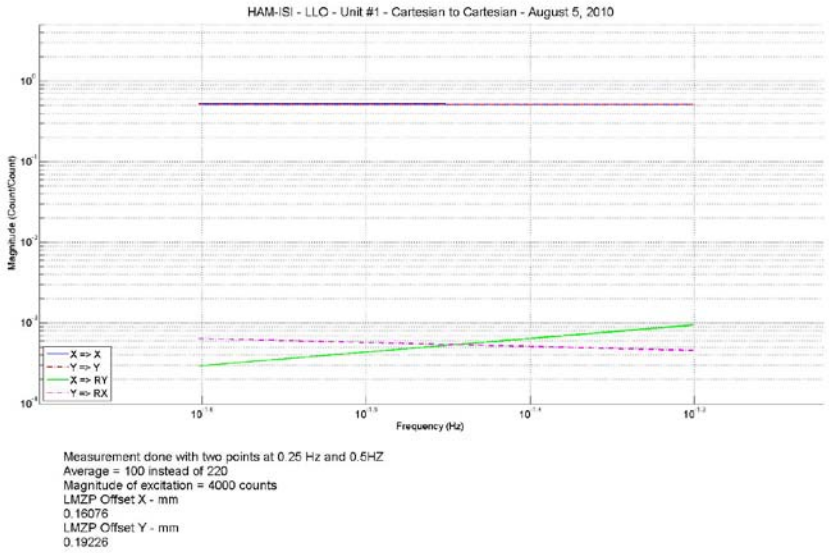


**Figure - Lower Zero moment plane – Main and cross coupling at low frequency**

**Acceptance criteria:**

- Vertical offset must be less than mm
- Horizontal offset must be less than mm

**Test result:** **Passed: ___** **Failed: ___**

- ***Step 20 - Damping loops***

**Filters used by Damping loops in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Damping_Loops

- G1ISIHAM_LLO_Unit_1_2010_08_10.txt (digitalized filters copied and rename to G1ISIHAM.txt in /opt/rtcds/geo/g1/chans)

**Scripts files for processing and plotting in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/
Damping_Loops_DTT_Powerspectrum_Transfer_functions

- HAM_ISI_LLO_unit1_Control_unlocked_no_damping_damping_100803.m

**Data files in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/
Damping_Loops_DTT_Powerspectrum_Transfer_functions

- Powerspectrum_table_unlocked_no_damping_damping.txt

**Figures in SVN at:**
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_1/Figures/Damping_Loops

- Damping_LOOP_GEO_Powerspectrum.fig
- Damping_LOOP_H1_H2_H3.fig
- Damping_LOOP_V1_V2_V3.fig
- Simulation_vs_experimental_Suppression.fig

- *Step 20.1 - Transfer functions - Simulation*

The following figures present the plant, controller, open loop, closed loop and sensitivity of vertical and horizontal damping loops. H1/V1 are plotted in solid line, H2/V2 are plotted in dash line, H3/V3 are plotted in dash-dot line.

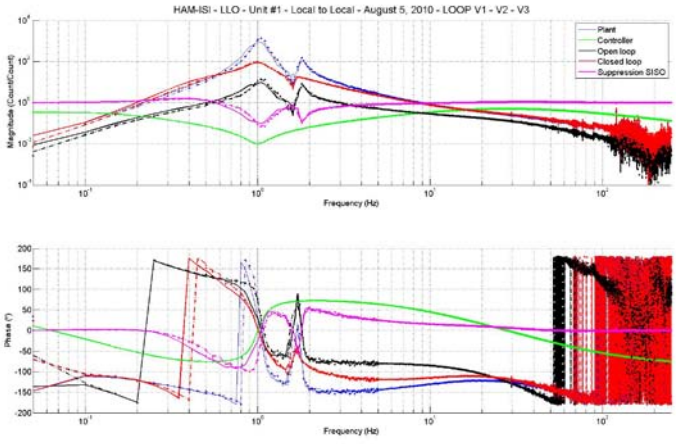


**Figure - Vertical damping loops - Simulation**

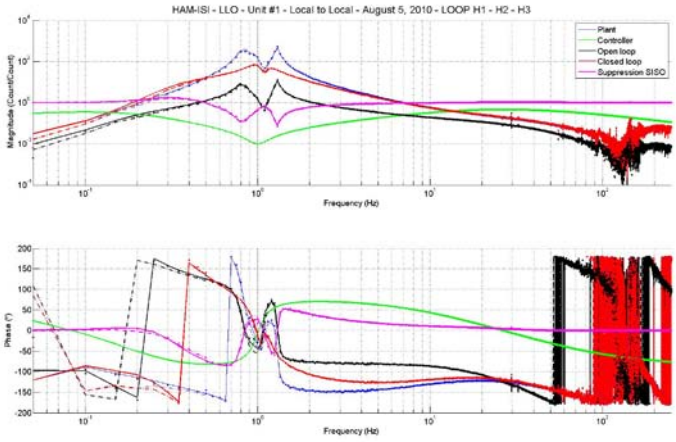


**Figure – Horizontal damping loops - Simulation**

### o *Step 20.2 - Powerspectrum – Experimental*

**Powerspectrum:**

The figure below shows power spectrum of Geophones when there when there is no damping loop and when all damping loops are engaged.

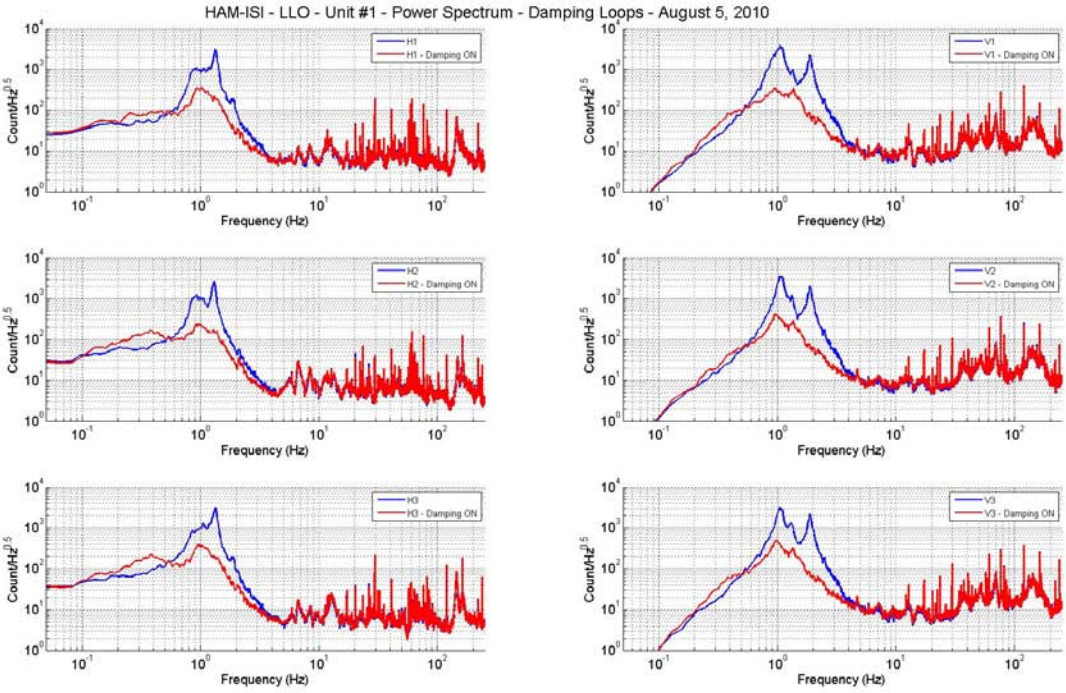


**Figure – Horizontal (left) and vertical (right) damping loops - Experimental**

**Sensitivity:**
The figure below compare the sensitivity ('Undamped/'Damped') of LLO HAM (Aug 2008) and LLO Unit 1. Performances are very similar, which confirms that we can use the damping loop as they are (modulo electronics change compensation). The plot also shows that the measured performance matches with the prediction.

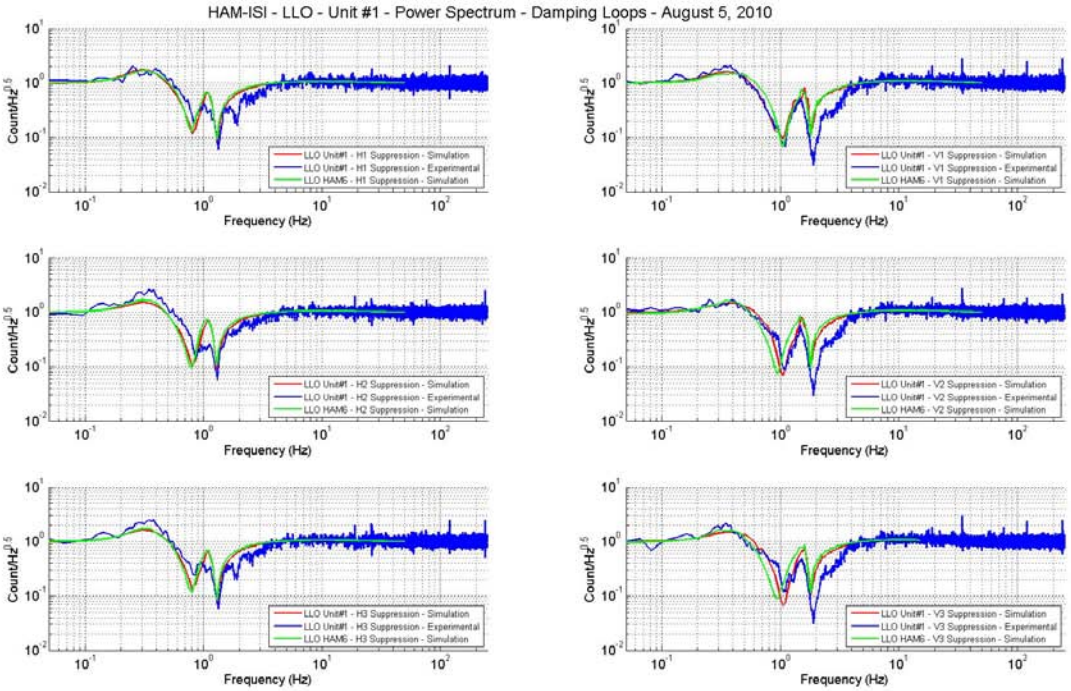


**Figure - Damping loop sensitivity**

**Acceptance criteria:**

- Ham 6 damping loop must implemented and stable with
  - Phase margin must be at least 45º
  - Gain margin must be at least 20dB

**Test result:** **Passed: ___** **Failed: ___**

# IV. Testing Summary