*LIGO Laboratory / LIGO Scientific Collaboration*

**LIGO- E1000313** *LIGO* April 4th, 2012

# aLIGO HAM-ISI, Pre-integration Test Report, Phase I,

# LHO Unit #4 (post-assembly, before storage, after replacement of faulty parts)

E1000313 – V1

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Distribution of this document:
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# *Introduction*

HAM-ISI Unit #4 was assembled during March 2012. The testing of this Unit is presented here. It started on March 28th 2012 and lasted until April 4th 2012.

Stage-0 L4Cs were not installed during tests. L4C brackets were installed.

The procedure document used to perform these tests is:

- E1000309–V9 - aLIGO HAM-ISI, Pre-Integration Testing Procedure, Phase I (post assembly, before storage)

The report done prior to HAM-ISI Unit #2 disassembly/reassembly is posted under V3:

- E1000311_aLIGO_SEI_Testing_Report_HAM-ISI_LHO_Unit_2_V3

Other useful information can be found in:

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

**Remark regarding SVN paths:**

**Units need to be tested under a folder that matches medm channels' names. Since MEDM channels' names all refer to HAMX during this phase of testing, units are all tested under:**

**/SeiSVN/seismic/HAM-ISI/X1/HAMX/**

**Once a unit is tested, a folder called after its order of assembly is created. For Unit #4 the name of this folder will be:**

**/SeiSVN/seismic/HAM-ISI/X1/Unit_4/**

**Test data is then moved from HAMX testing folder to this final folder. All the data related to the Phase I testing of this unit is then stored in this folder. The data set names, the location of the test results, and the locations of the programs used to obtain them are specified along this document.**

**Even if they are tested under HAMX, units are called per their order of assembly in programs, figures and data files.**

# I. Pre-Assembly Testing

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

| 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 |
|---|---|---|---|---|---|---|---|
| 12046 | 11881 | NR | x | ~2.057 | X | ~.01 | x |
| 12018 | 11872 | NR | x | ~2.057 | X | ~.01 | x |
| 12034 | 11933 | NR | x | ~2.057 | X | ~.01 | x |
| 12042 | 11932 | NR | x | ~2.057 | X | ~.01 | x |
| 12070 | NR | NR | x | NR | X | NR | x |
| 12081 | NR | NR | x | NR | X | NR | x |

Note: The back panel reads 0.508V/0.001"
NR: not recorded

Sensors noise spectra measured before baking E1000257, and before shielding per procedure T1000636:

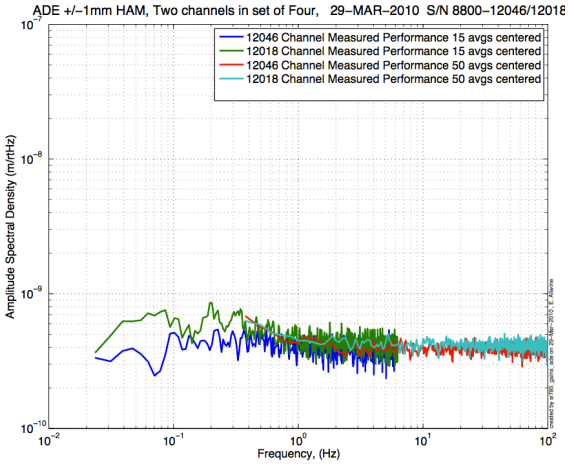



**Figure - H1 and V1 sensor noise**

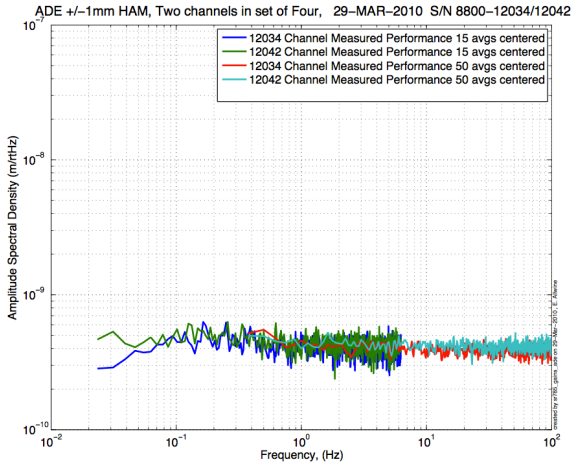



**Figure - H2 and V2 sensor noise**

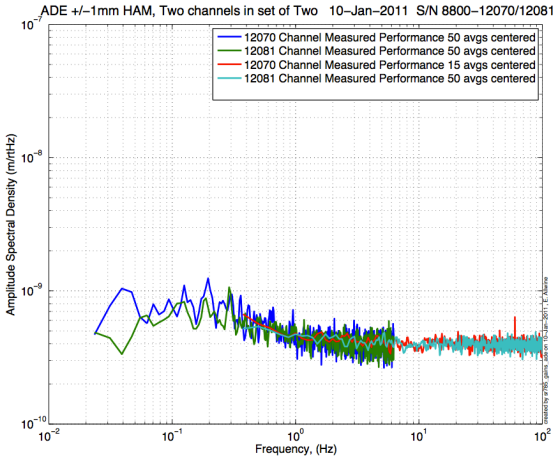



**Figure - H3 and V3 sensor noise**

Issues/difficulties/comments regarding this test:

- The CPS #12070 (H3) #12081 (V3) are borderline. Their spectra are within requirements at the requirement points but magnitudes get higher passed these points.
- Test information is missing for CPSs 12070 and 12081.

**Acceptance Criteria:**

- Power spectrum magnitudes must be lower than:
  - 9.e-10 m/√Hz at 0.1Hz
  - 6.e-10 m/√Hz at 1Hz

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

- ***Step 2: GS13***

**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.
**Power spectra measured at reception, after shipment from LLO, can be found at**
\SeismicSVN\ seismic\Common\Data\aLIGO_GS13_TestData_LHO\

aLIGO GS13 Testing page is E1100367. It contains links to:

- LIGO-E1000058: aLIGO GS-13 Status Chart
- LIGO-24: aLIGO GS-13 as received testing results
- LIGO-E1100394: aLIGO GS-13 prior shipping testing results
- LIGO-E1100395: aLIGO GS-13 Post Modification testing results
- LIGO-F0900070: GS-13 Inspection Checklist

| | | Corner 1 | Corner 2 | Corner 3 |
|---|---|---|---|---|
| V | Pod | 88 | 14 | 30 |
| | Instrument | 692 | 693 | 715 |
| H | Pod | 44 (2) | 93 | 07 (2) |
| | Instrument | 782 | 814 | 788 |

**Table- GS13 instrument and Pod S/Ns**

(2): Taken from Unit #2

- ***Step 2.1 – Horizontal GS-13s***

**Huddle testing**

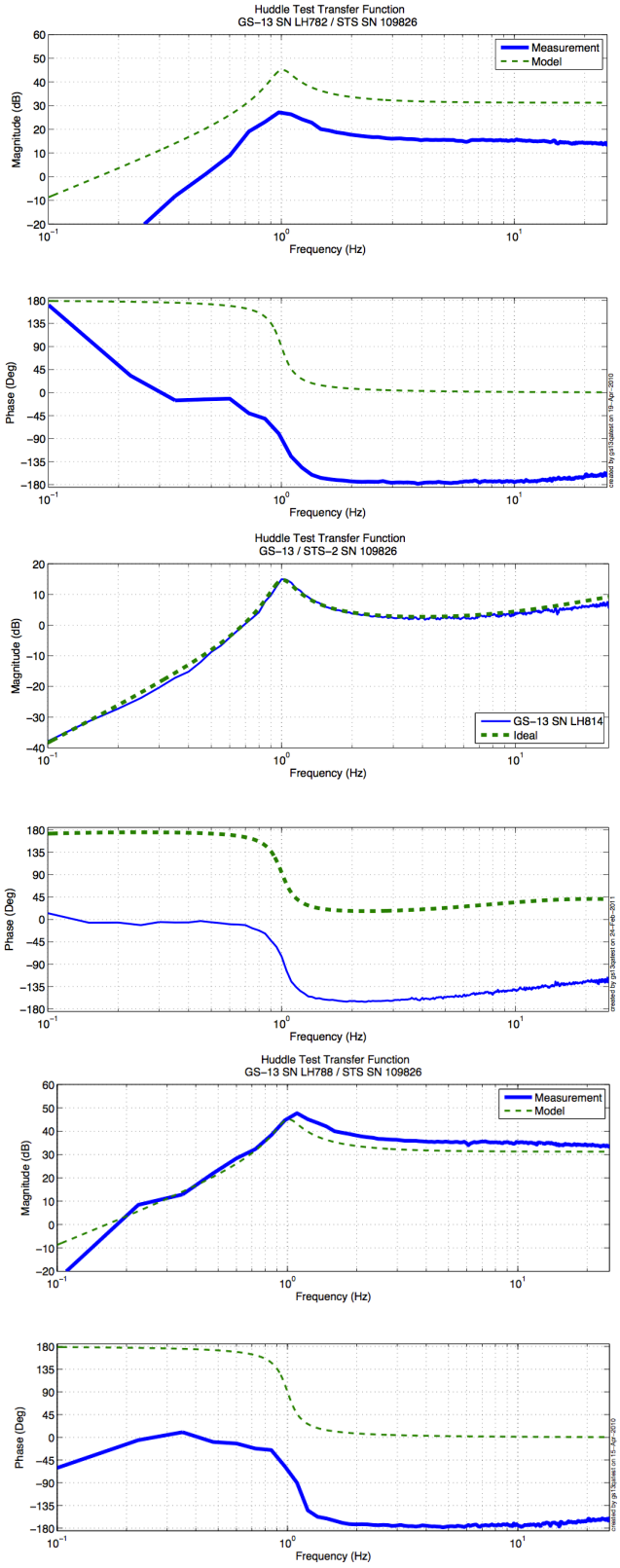



**Figure - Huddle testing of Horiz GS-13 782(H1), 814(H2), and 788(H3) after aLIGO modifications**

- ***Step 2.2 – Vertical GS-13s***

**Huddle testing**

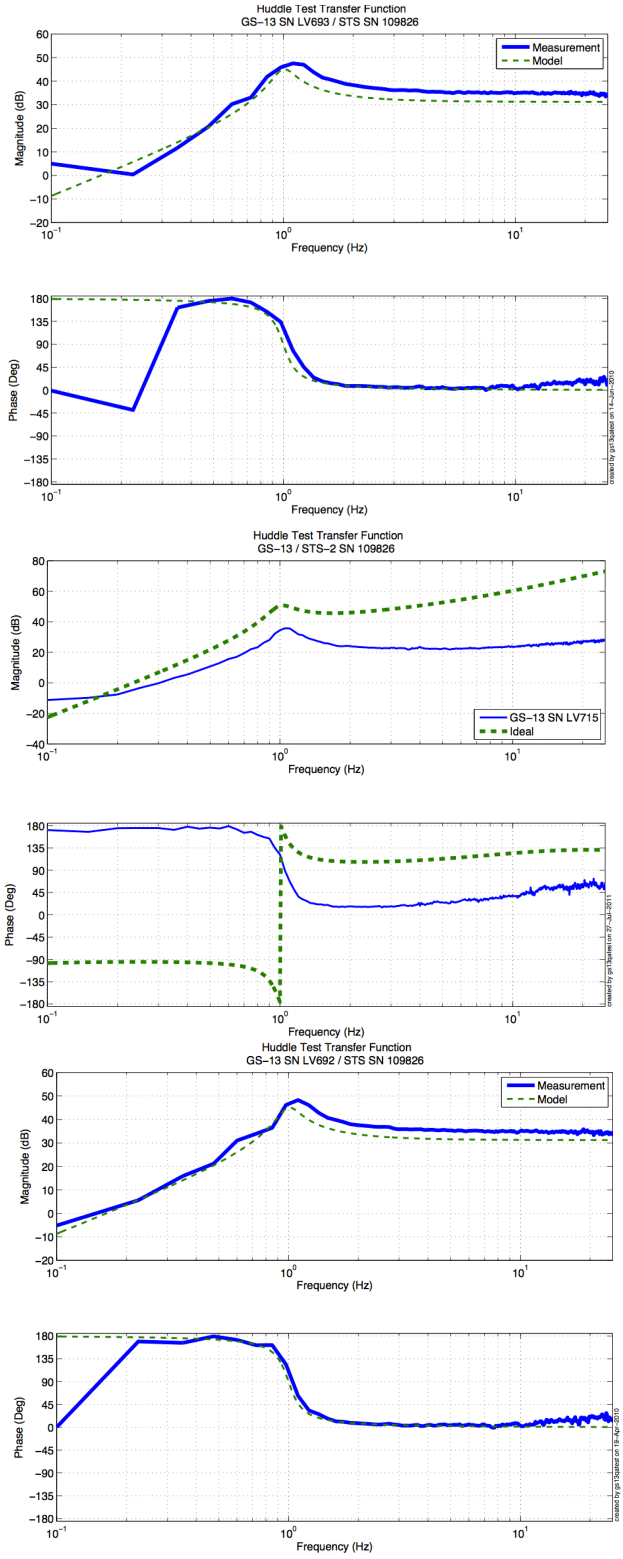



**Figure - Huddle testing of Vertical GS-13 693(V1), 715(V2), and 692(V3) after aLIGO modifications**

## Driven testing

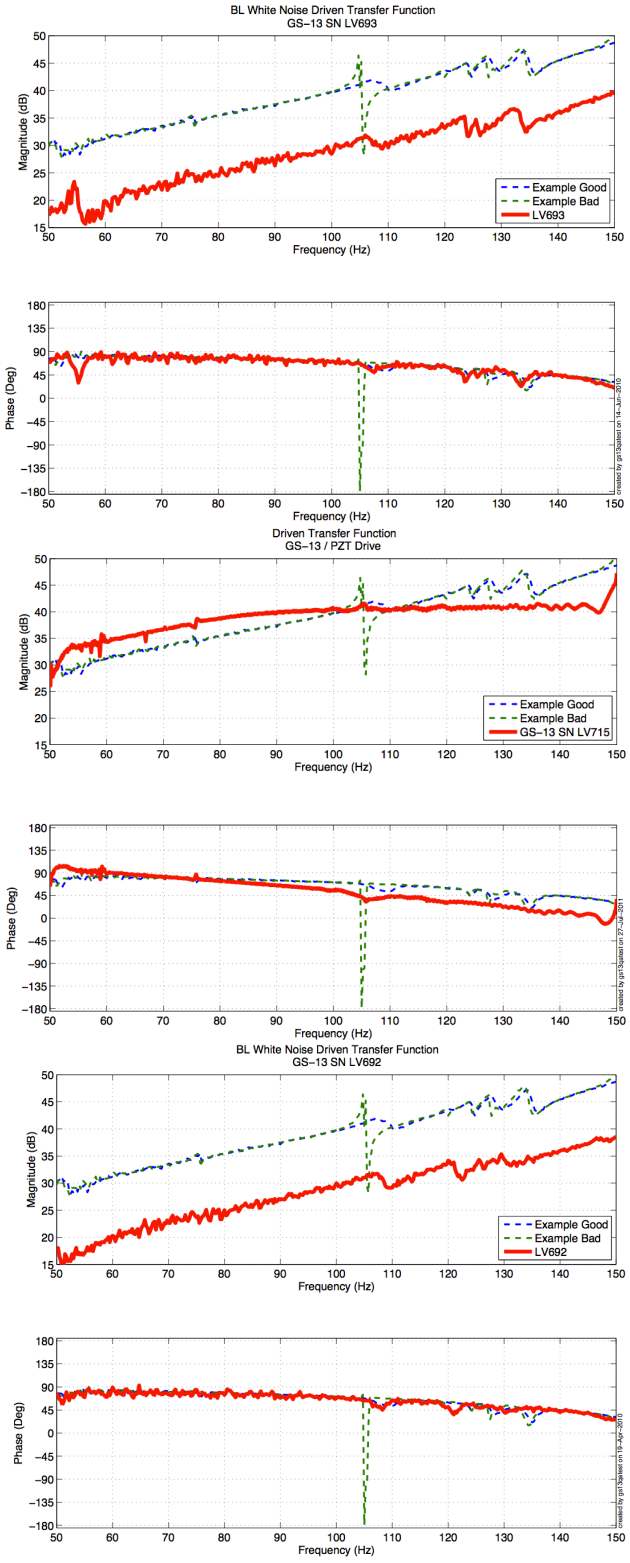



**Figure - Driven testing of Vertical GS-13 693(V1), 715(V2), and 692(V3) after aLIGO modifications**

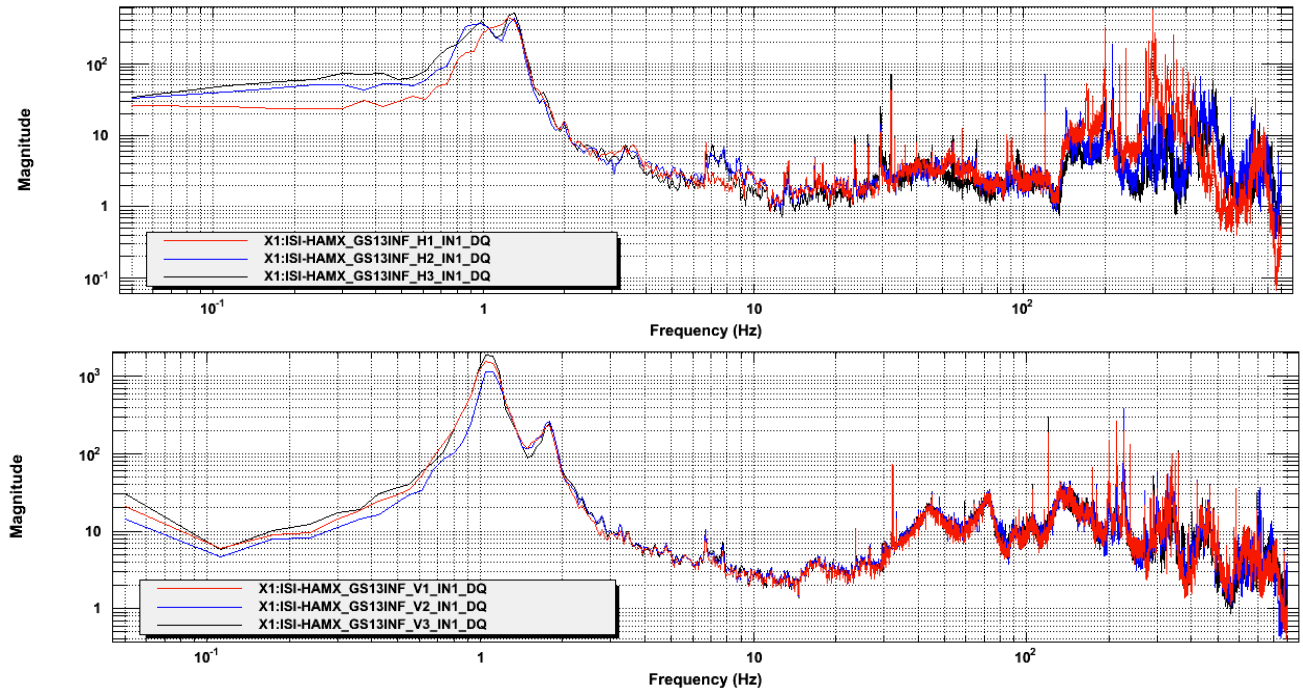



**Figure - GS13 Power Spectra after installation at LHO**

Issues/difficulties/comments regarding this test:

5 GS13-pods were shipped from LLO (shipment #3417) to be installed on this Unit. This shipment contained 3 Vertical GS13s, 2 horizontal ones. The third horizontal GS13 needed to test this Unit was supposed to be taken from Unit #2 which was tested just before. However, One of the horizontal pods shipped from LLO (Pod #24) was malfunctioning, and discarded, after reception (see LHO aLog # 2449). Finally, two GS13 pods were taken from HAM-ISI Unit #2 to complete the production-GS13-set of HAM-ISI Unit #4:

- Pod #44, horizontal
- Pod #07, horizontal

**Acceptance Criteria:**

- GS13 have already been tested at LLO. GS13 Inspection/Pod Assembly is described in document D047810. Checklist is defined in F090070-v6
- After reception the geophones at LHO, ASDs of the geophones must confirm that they are still functioning after shipping.

**Test result:** **Passed: X** **Failed: ____**

- ***Step 3: Actuators***

Actuator data can be found at: T0900564-V2. Actuator inventory is made at Section II – Step 1.

| | |
|---|---|
| Actuator Serial #: L124<br>Operator Name: Gordon, Matt<br>Date: 1/29/2010 Time: 1:42 PM<br>Actuator Coil Resistance: 6.38 Ohms, PASS<br>Ambient Temperature: 71.3 F<br>Hi Pot Test Results: 1000 MOhms, PASS<br>X Travel Limit (inches): 0.524<br>Y Travel Limit (inches): 0.204<br>Z Travel Limit (inches): 0.503 | Actuator Serial #: L108<br>Operator Name: Gordon, Matt<br>Date: 1/30/2010 Time: 10:04 AM<br>Actuator Coil Resistance: 6.45 Ohms, PASS<br>Ambient Temperature: 64.8 F<br>Hi Pot Test Results: 1000 MOhms, PASS<br>X Travel Limit (inches): 0.527<br>Y Travel Limit (inches): 0.205<br>Z Travel Limit (inches): 0.505 |
| Actuator Serial #: L099<br>Operator Name: Gordon, Matt<br>Date: 1/28/2010 Time: 2:36 PM<br>Actuator Coil Resistance: 6.46 Ohms, PASS<br>Ambient Temperature: 72.0 F<br>Hi Pot Test Results: 1000 MOhms, PASS<br>X Travel Limit (inches): 0.528<br>Y Travel Limit (inches): 0.204<br>Z Travel Limit (inches): 0.503 | Actuator Serial #: L051<br>Operator Name: Gordon, Matt<br>Date: 9/24/2009 Time: 8:35 AM<br>Actuator Coil Resistance: 6.38 Ohms, PASS<br>Ambient Temperature: 68.8 F<br>Hi Pot Test Results: 1000 MOhms, PASS<br>X Travel Limit (inches): 0.520<br>Y Travel Limit (inches): 0.205<br>Z Travel Limit (inches): 0.506 |
| Actuator Serial #: L107<br>Operator Name: Gordon, Matt<br>Date: 1/30/2010 Time: 10:22 AM<br>Actuator Coil Resistance: 6.58 Ohms, PASS<br>Ambient Temperature: 64.8 F<br>Hi Pot Test Results: 1000 MOhms, PASS<br>X Travel Limit (inches): 0.528<br>Y Travel Limit (inches): 0.205<br>Z Travel Limit (inches): 0.503 | Actuator Serial #: L064<br>Operator Name: Gordon, Matt<br>Date: 9/25/2009 Time: 9:50 AM<br>Actuator Coil Resistance: 6.38 Ohms, PASS<br>Ambient Temperature: 72.7 F<br>Hi Pot Test Results: 1000 MOhms, PASS<br>X Travel Limit (inches): 0.529<br>Y Travel Limit (inches): 0.205<br>Z Travel Limit (inches): 0.505 |

**Acceptance Criteria:**

- Actuators were previously tested and results are reported in T0900564-V2.

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

# II. Tests to be performed during assembly

- ***Step 1: Parts Inventory (E1000052)***

| DCC Number | Part name | Configuration | Corner 1 S/N | Corner 2 S/N | Corner 3 S/N |
|---|---|---|---|---|---|
| D071001 | Stage 0 base | NA | 11 | | |
| D071051 | Stage 1 base | NA | 11 | | |
| D071050 | Optical table | NA | 12 | | |
| D071002 | Spring Post | NA | 18 | 19 | 16 |
| D071100 | Spring | NA | 12 | 8 | 47 |
| D071102 | Flexure | NA | 10 | 17 | 9 |
| ADE | Position sensor | Horizontal | 12046 Master 0 | 12034 slave 180 | 12070 Slave 0 |
| | | Vertical | 12018 slave 180 | 12042 slave 0 | 12081 Slave 180 |
| D047812 | GS-13 pod | Horizontal | 44 (2) | 93 | 07 (2) |
| | | Vertical | 88 | 14 | 30 |
| D047823 | L4C pod | Horizontal | NA | NA | NA |
| | | Vertical | NA | NA | NA |
| D0902749 | Actuator | Horizontal | 124 | 99 | 107 |
| | | Vertical | 108 | 51 | 64 |

**Table – Parts inventory**

| Cable Connects | | Cable S/N | | |
|---|---|---|---|---|
| Part Name | Configuration | Corner 1 | Corner 2 | Corner 3 |
| GS13 | Horizontal | S110668 (100”) | S1106657 | S1104775 (40”) |
| GS13 | Vertical | | | |
| L4C | Horizontal | NA | NA | NA |
| L4C | Vertical | NA | NA | NA |
| Actuator | Horizontal | S1104758 | S1104764 | S1104759 |
| | Vertical | S1104746 | S1104757 | S1104770 |

**Table – Cables inventory**

NR: Not recorded; NA: Not applicable
2: Production GS13 taken from HAM-ISI Unit #2.

- ***Step 2: 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 3: Check gaps under Support Posts***

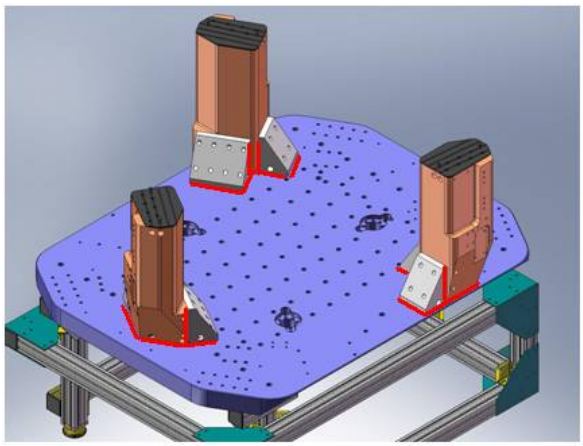


**Figure - Showing edges that need checked on support posts and gussets**

**Acceptance Criteria:**

- 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 4: Pitchfork/Boxwork flatness before Optical Table install***

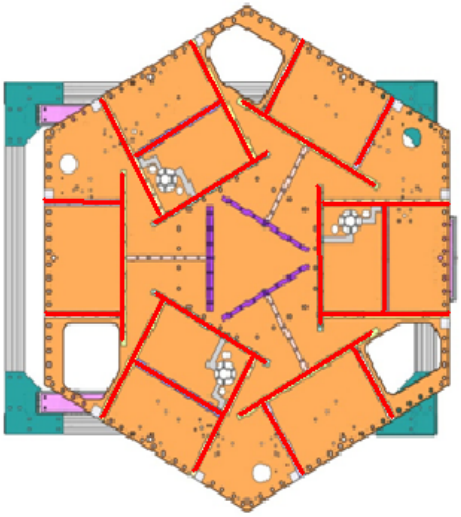


**Figure – Showing what needs to be checked on Boxworks and Pitchforks**

**Acceptance Criteria:**

- Shim inserted won't pass between parts.

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

- ***Step 5: Blade spring profile***

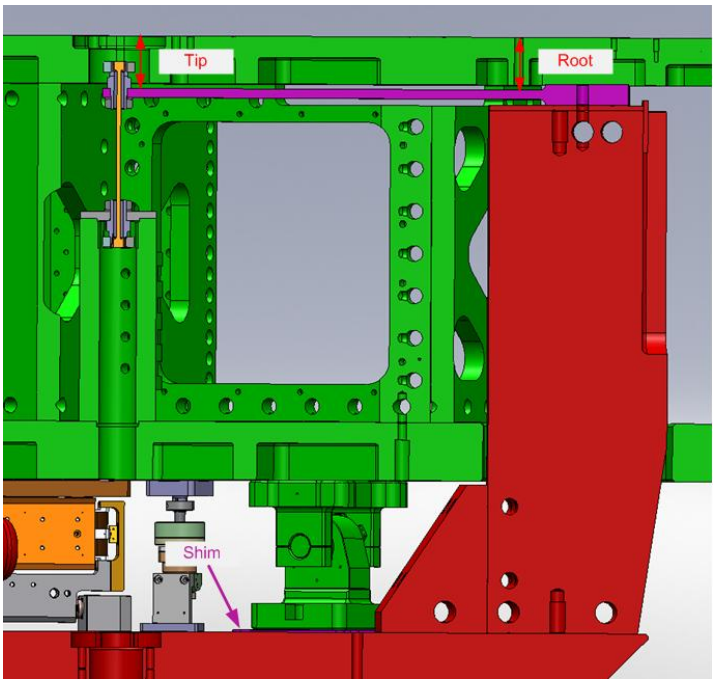



**figure – Blade spring profile measurement points**

| Blade # | Root (Mils) | Tip(Mils) | Flatness (mils) |
|---|---|---|---|
| 1 | 640 | 633 | 7 |
| 2 | 644 | 631 | 13 |
| 3 | 640 | 637 | 3 |

**Table 1 - Blade profile**

**Acceptance Criteria:**

- Blades must be flat within 0.015" inches.

Note that the tip measurement should be constant and that root value can be impacted by shims change.

**Test result:** **Passed: X** **Failed: ____**

- ***Step 6: Gap checks on actuators-after installation on Stage 1***

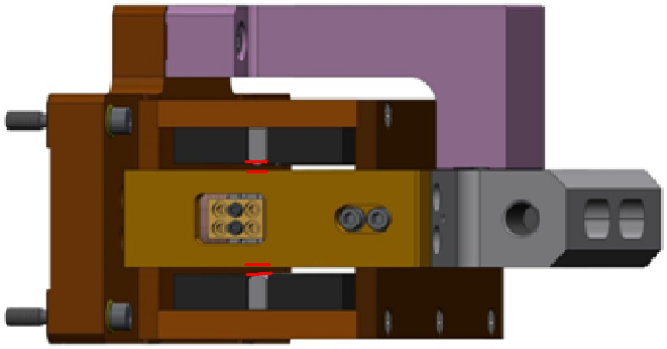


**Figure - Showing gaps that need to be checked on actuators.**

Issues/difficulties/comments regarding this test:
Since layers of shims are difficult to use accurately, a Go (70mils shim set) vs. No Go (90 mils shim set) technique was used for this test. To pass the test an actuator gap has to allow the 70mils shim set to be inserted and refuse the 90mils shim set.

The gaps on the backside of horizontal actuators are hard to access.

**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 7: Check level of Stage 0***

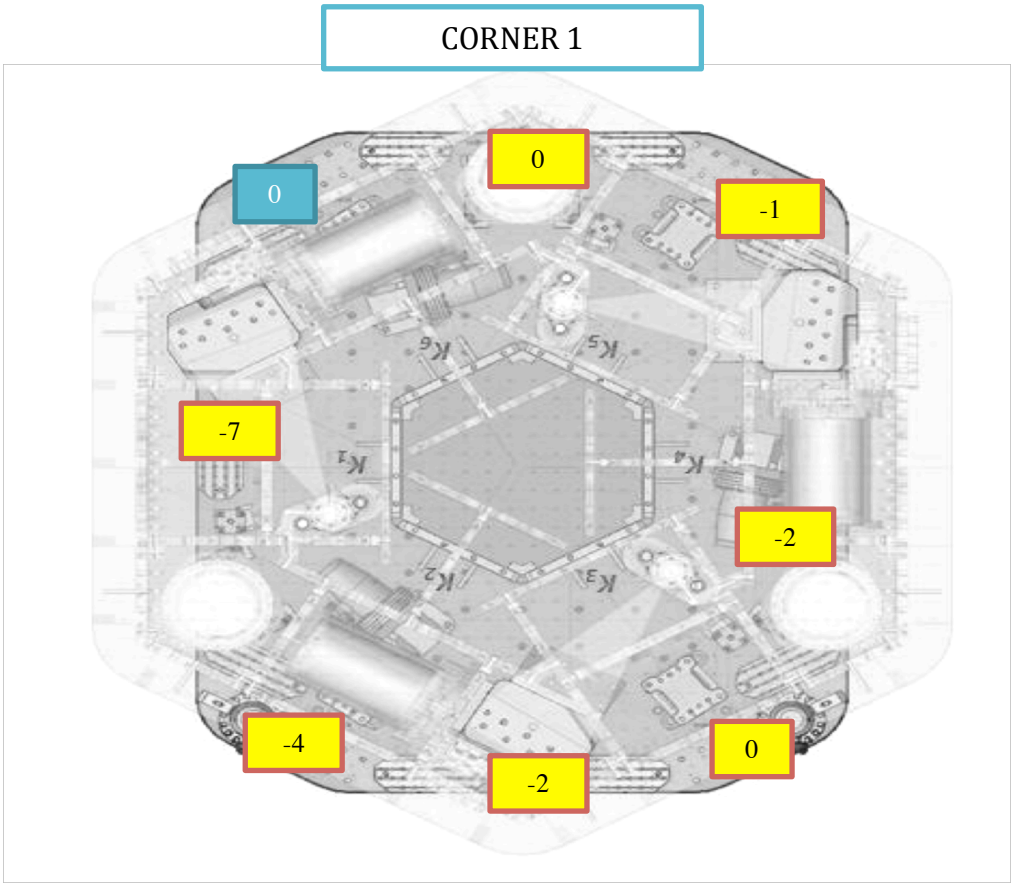



**Figure – Level measured on Stage 0**

Issues/difficulties/comments regarding this test:
The accuracy of the measurement limited by the measurement tool: optical level + ruler on a block. The ruler only has 1/100" graduations. Values are deduced from the relative distance to graduations. The uncertainty is about 1mil.

Max angle is calculated between the opposite points that have the most different level.

**Max angle=0.005/57 (± 0.001/57) = 87.7 (±17.4) µrad**

**Acceptance Criteria**

- The maximum angle of the table with the horizontal mustn't exceed ~100µrad

**Test result:** **Passed:** X **Failed:** ____

- ***Step 8: Check level of Stage 1 Optical Table***

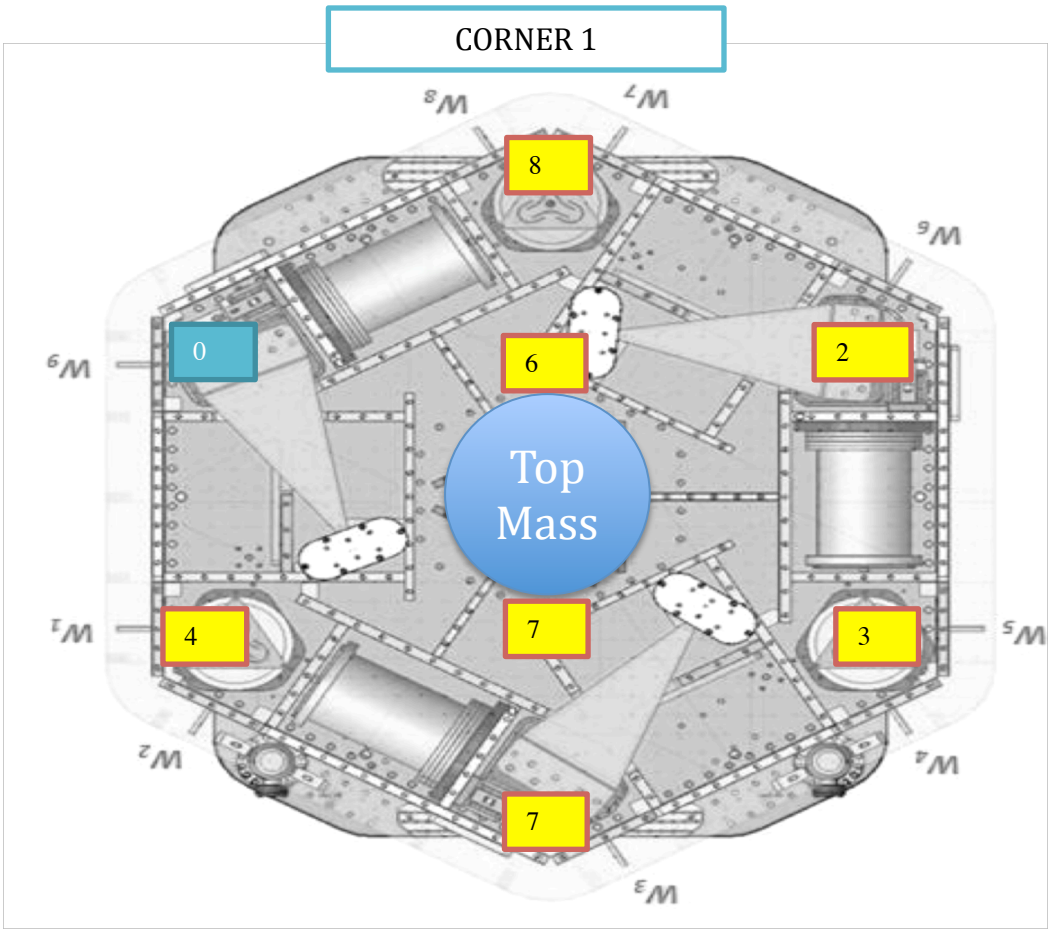



**Figure – Level measured on Stage 1**

Issues/difficulties/comments regarding this test:
The accuracy of the measurement is limited by the measurement tool: optical level + ruler on a block. The ruler only has 1/100" graduations. Values are deduced from the relative distance to graduations. The uncertainty is about 1mil.

Max angle is calculated between the opposite points that have the most different level.

**Max angle = 0.002/76 (± 0.001/76) = 26.3 (± 13.1) µrad**

**Acceptance Criteria**

- The maximum angle of the table with the horizontal mustn't exceed ~100µrad

**Test result:** **Passed: X** **Failed: ____**

**Note:**
The level of the optical table is within requirement. However, its flatness seems a bit off. The pattern suggested by the measurement is a *flipped potato chip*, which is in contradiction with the location of the top mass. This shape might be caused by variations among the tolerance range for the height of the vertical walls of the ISI.

- ***Step 9: Mass budget***

| | 00 | 01 | 02 | 03 | 04 | 05 | 06 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.6 | 1.1 | 2.2 | 4.5 | 7.9 | 15.6 | 27.2 | lbs | kgs |
| W9 | | | | 1 | 1 | 1 | 1 | 55.2 | 25.04 |
| W1 | | | | | 1 | 1 | 1 | 50.7 | 23.00 |
| W2 | 1 | | | | | | 1 | 27.8 | 12.61 |
| W3 | | | | | | 1 | 1 | 42.8 | 19.41 |
| W4 | | | | | | 1 | 1 | 42.8 | 19.41 |
| W5 | 1 | | | 1 | 2 | | 1 | 48.1 | 21.82 |
| W6 | 1 | | | | 1 | | 1 | 35.7 | 16.19 |
| W7 | | | | 1 | | 1 | 1 | 47.3 | 21.45 |
| W8 | | 1 | | | 1 | | 1 | 36.2 | 16.42 |
| Side Masses Total | 3 | 1 | 0 | 3 | 6 | 5 | 9 | 386.6 | 175.36 |

**Table – Wall masses distribution**

| | 00 | 01 | 02 | 03 | 04 | 05 | 06 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.6 | 1.1 | 2.2 | 4.5 | 7.9 | 15.6 | 27.2 | lbs | kgs |
| K1 | | | | | | 2 | | 31.2 | 14.15 |
| K2 | | | | | 1 | | 1 | 35.1 | 15.92 |
| K3 | | | | | | 2 | | 31.2 | 14.15 |
| K4 | | | | | 1 | | 1 | 35.1 | 15.92 |
| K5 | | | | | | 2 | | 31.2 | 14.15 |
| K6 | | | | | 1 | | 1 | 35.1 | 15.92 |
| Keel Masses Total | 0 | 0 | 0 | 0 | 3 | 6 | 3 | 198.9 | 90.22 |

**Table – Keel masses distribution**

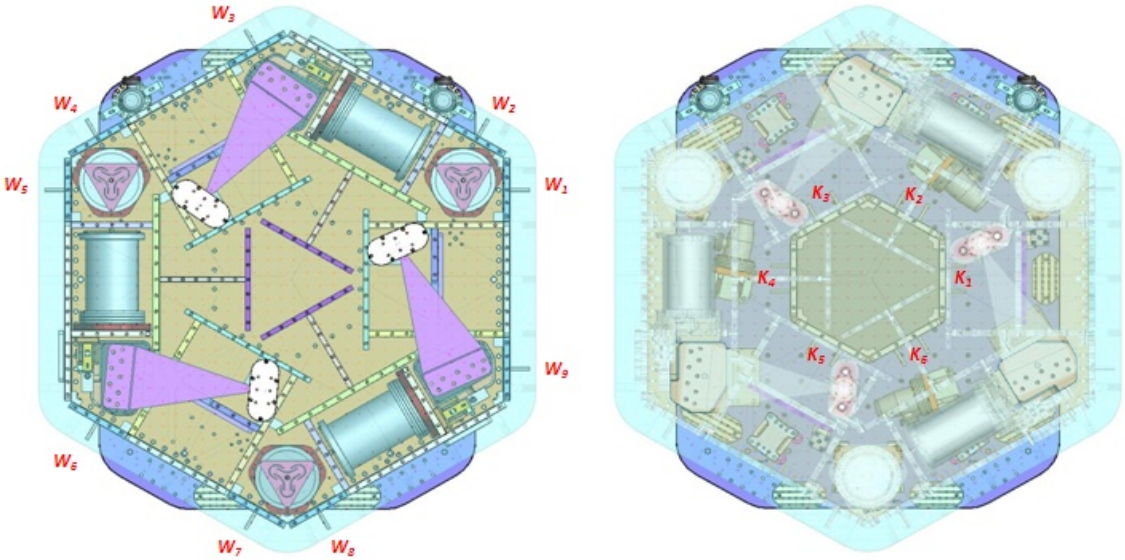
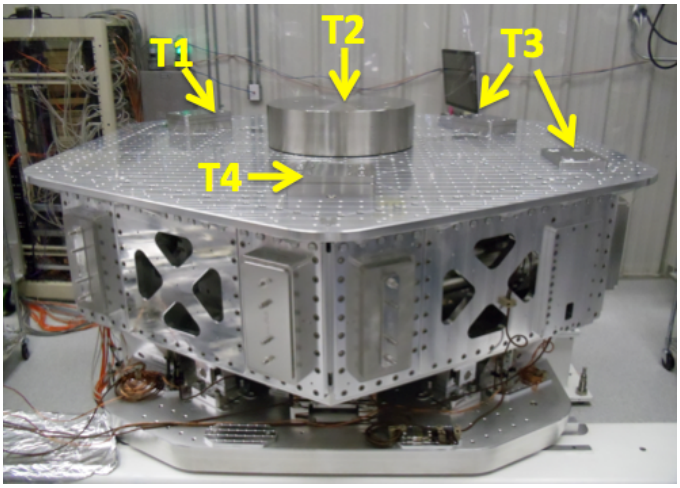



**Figure – Wall Masses (W) and Keel masses (K) location.** ***South of picture = corner 1***

| | Mass (kg) |
|---|---|
| T1 | 20.00 |
| T2 | 270.79 |
| T3 | 20.00 |
| T4 | 15.00 |
| Total | 325.79 |

**Table – Optic table masses distribution**




**Picture – Optic table masses distribution**

| | Side | Keel | Top | Total |
|---|---|---|---|---|
| Weigh (kg) | 175.36 | 90.22 | 325.79 | 591.37 |

**Table – Mass budget sum up**

Issues/difficulties/comments regarding this test:

- T2 mass evaluated at nominal value: 270.79lbs. Gauge not available for measurement.
- A few shims were used for balancing. Their weight is negligible in comparison with the mass budget. Hence their weight is not reported in the mass budget.

**Acceptance Criteria**

The Mass budget must be

- 579.1 Kg (cf. E1100427)+/-25Kg (5%)

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

- ***Step 10: Shim thickness***

| Lockers | Shim thickness (mils) |
|---|---|
| A | 126 |
| B | 126 |
| C | 122 |
| D | 122 |

**Table – Shims Thickness**

**Acceptance Criteria**

- The shim thickness should be 125 mils +/-5

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

- ***Step 11: Lockers adjustment***

| D.I. at Locker | Vertical D.I. | Horizontal D.I. |
|---|---|---|
| A | -0.1 | 0.4 |
| B | 1 | -0.8 |
| C | -0.5 | -1.2 |
| D | -0.9 | -0.4 |

**Table – Dial indicators read-out (in thousands of an inch)**

**Acceptance Criteria**

- Vertical and horizontal displacement near the lockers must be lower than 2 mils (0.002”

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

# III. Tests to be performed after assembly

- ***Step 1 - Electronics Inventory***

| Hardware | LIGO reference | S/N |
|---|---|---|
| **Coil driver** | D0902744 | S1000266 |
| | | S1000269 |
| **Anti Image filter** | D070081 | S1000250 |
| **Anti aliasing filter** | D1000269 | S1102694 |
| | | S1102679 |
| **Interface chassis** | D1000067 | 1102223 |
| | | 1102224 |
| | | 1102214 |

**Table - Inventory electronics**

**Acceptance Criteria**

- Inventory is complete

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

- ***Step 2 - Set up sensors gap***

| | Locked, 10 Kg masses at each corners | | Locked /no mass | | Unlocked /no mass | |
|---|---|---|---|---|---|---|
| **Table locked** | **ADE boxes on** | | **ADE boxes on** | | **ADE boxes on** | |
| **Sensors** | **Offset (Mean)** | **Std deviation** | **Offset (Mean)** | **Std deviation** | **Offset (Mean)** | **Std deviation** |
| **H1** | -300.91 | 7.44 | -179.25 | 7.54 | 38.26 | 15.71 |
| **H2** | 356.80 | 8.36 | 358.58 | 8.14 | 114.47 | 13.45 |
| **H3** | -169.42 | 8.08 | -159.24 | 9.34 | 380.66 | 23.62 |
| **V1** | -206.09 | 6.93 | -66.94 | 7.79 | -544.90 | 15.86 |
| **V2** | -168.09 | 10.01 | 38.80 | 9.72 | -463.59 | 14.48 |
| **V3** | -41.51 | 11.80 | -36.04 | 10.08 | -55.66 | 18.79 |

**Capacitive position sensor readout after gap set-up**

**Acceptance criteria:**

- All mean values must be lower than +/-400 cts (a bit less than .0005").
- All standard deviations below 5 counts.
- No cross talk

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

**Note:** Failed because of standard deviation. However, a CPS was set on a test-jig and featured 4.3 counts of standard deviation, which is within specs. Hence, the high standard deviation observed is correlated to the 10Hz-100Hz peaks observed on the locked/unlocked GS13 and CPS ASDs. As shown in *SEI Logbook entry #15*, these peaks are caused by ground motion. Hence, high standard deviations should not be associated with sensor noise.

**Note:** Vertical CPSs are out of requirement when the ISI is unlocked. This little issue will be solved when the balancing was perfected for the next steps of testing.

- ***Step 3 - Measure the Sensor gap***

Issues/difficulties/comments regarding this test:
Measured in the previous step. Waived to avoid scratching targets.

**Acceptance criteria:**
Sensors gap measured on the jig and on the optical table must be:
- 0.080" +/-0.002"

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

- ***Step 4 - Check Sensor gaps after the platform release***

| | Table locked | | Table unlocked | | |
|---|---|---|---|---|---|
| **Sensors** | **Mean** | **Std Deviation** | **Mean** | **Std Deviation** | **Difference** |
| **H1** | -179.25 | 7.54 | 38.26 | 15.71 | 217.51 |
| **H2** | 358.58 | 8.14 | 114.47 | 13.45 | 244.11 |
| **H3** | -159.24 | 9.34 | 380.66 | 23.62 | 539.90 |
| **V1** | -66.94 | 7.79 | -544.90 | 15.86 | 477.97 |
| **V2** | 38.80 | 9.72 | -463.59 | 14.48 | 502.39 |
| **V3** | -36.04 | 10.08 | -55.66 | 18.79 | 19.62 |

**Table – Sensor gaps after platform release**

**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")
- All mean values must be lower than:
  - 2000 cts for horizontal sensors (~0.0025")
  - 2000 cts for vertical sensors (~0.0025")

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

- ***Step 5 – Performance of the limiter***

- ***Step 5.1 - Test Nº1 - Pushing "in the general coordinates"***

| Pushing Z,-Z | CPS read out | | Calculated after calibration | | ROM |
|---|---|---|---|---|---|
| **Sensors** | **UP (Counts)** | **Down (Counts)** | **UP (mil)** | **Down (mil)** | |
| **V1** | 19000 | -19000 | 22.4 | -22.4 | 38000 |
| **V2** | 20000 | -18000 | 23.6 | -21.3 | 38000 |
| **V3** | 19500 | -20000 | 23.0 | -23.6 | 39500 |

| **Pushing RZ, -RZ** | **CPS read out** | | **Calculated after calibration** | | ROM |
|---|---|---|---|---|---|
| **Sensors** | **CCW (+RZ)** | **CW(-RZ)** | **CW (mil)** | **CCW (mil)** | |
| **H1** | -22200 | 22300 | -26.2 | 26.3 | 44500 |
| **H2** | -19200 | 22400 | -22.7 | 26.5 | 41600 |
| **H3** | -22000 | 21200 | -26.0 | 25.0 | 43200 |

**Table - Optic table range of motion**

- ***Step 5.2 - Test Nº2 – Pushing "locally"***

| **Pushing Locally** | **Push in positive direction** | **Push in negative direction** | **Railing** | **Actuator Gap Check** | **ROM** |
|---|---|---|---|---|---|
| **H1** | -23000 | 24800 | | **X** | 47800 |
| **H2** | -21000 | 24900 | | **X** | 45900 |
| **H3** | -26900 | 23000 | | **X** | 49900 |
| **V1** | 20400 | -19600 | | **X** | 40000 |
| **V2** | 32200 | -32600 | **X** | **X** | 64800 |
| **V3** | 17500 | -22000 | | **X** | 39500 |

**Table - Optic table range of motion**

Issues/difficulties encountered during this test:

- Contact points are difficult to check on vertical actuators.
- V3 (pushing locally) appears borderline. However it is not during step 10 which has been performed after perfecting the locker's adjustment.

**Acceptance criteria:**

- The vertical sensor readout must be positive when the optic table is pushed in the +Z direction
- The horizontal sensor readout must be negative when the optic table is pushed in the +RZ direction
- **Step 5.1**
  - Absolutes value of all estimated motions must be higher than 16000counts (~0.020")
- **Step 5.2**
  - 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: __X__** **Failed: ___ .**

- ***Step 6 - Position Sensors unlocked/locked Power Spectra***

**Scripts files for processing and plotting in SVN at:**
/SeiSVN/seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/

- ASD_Measurements_Locked_Unlocked_HAM_ISI.m

**Data in SVN at:**
SeiSVN/seismic/ HAM-ISI/X1/HAMX/Data/Spectra/Undamped/

- LHO_ISI_UNIT_4_ASD_m_CPS_T240_L4C_GS13_Locked_vs_Unlocked_2012_03_28.mat

**Figures in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/Figures/Spectra/Undamped

- LHO_ISI_UNIT_4_PSD_m_GS13_Locked_vs_Unlocked_2012_03_28.fig
- LHO_ISI_UNIT_4_PSD_m_CPS_ Locked_vs_Unlocked_2012_03_28.fig

Locked/Unlocked Power Spectra are presented below.

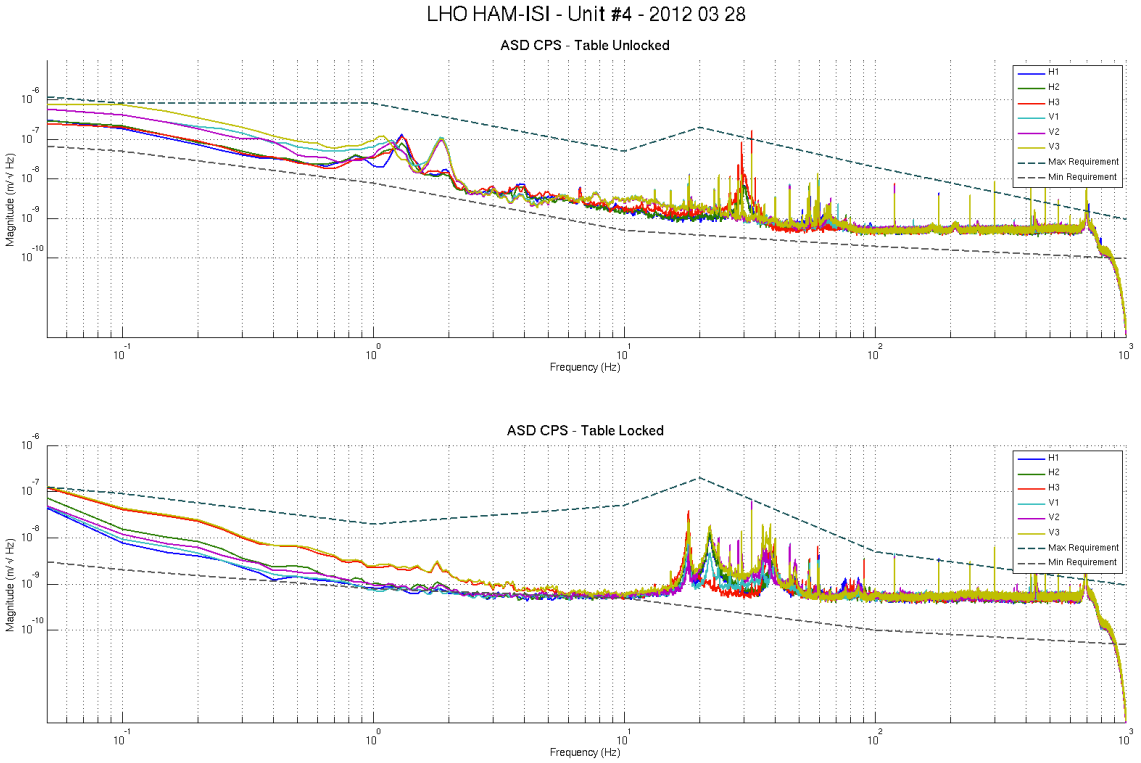



**Figure - Calibrated CPS power spectra**

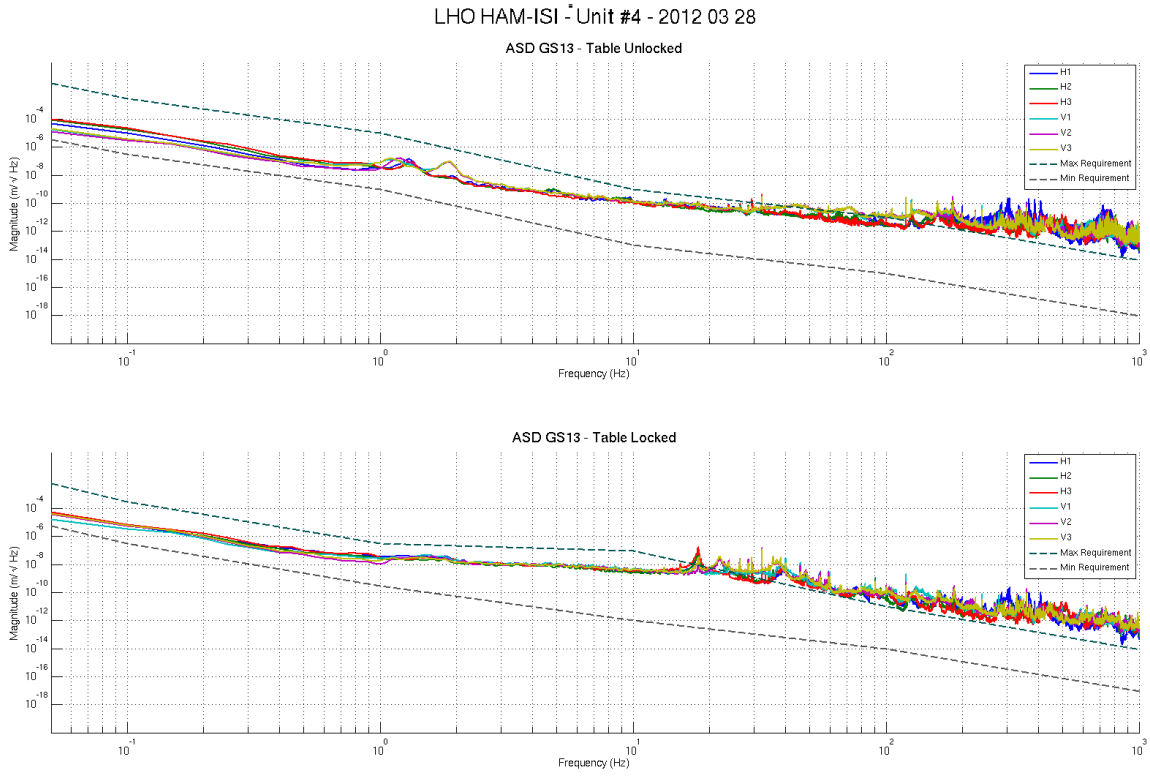



**Figure – Calibrated GS13 Power spectra**

Issues/difficulties/comments regarding this test:

- 10Hz-100Hz peaks were investigated for the testing phase I of Unit #3 (HAM10), and reported in Part 1, last step: *Capacitive Position Sensor Investigation*, of the related report (Document #E1000312-v3)

**Acceptance criteria:**

- No cross talk (peaks at low frequencies + harmonics on measurements)
- Magnitudes of power spectra must be between requirement curves

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

**Note:**
When a seismometer fails, its low frequency response is affected. Spectra are within requirements in low frequency. The GS13s installed on this unit are functional.

- ***Step 7 - GS13 power spectrum -tabled tilted***

**Scripts files for processing and plotting in SVN at:**
SeiSVN/seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- ASD_Measurements_Stages_Tilted_HAM_ISI.m

**Data in SVN at:**
SeiSVN/seismic/ HAM-ISI/X1/HAMX/Data/Spectra/Undamped/
- LHO_ISI_UNIT_4_ASD_m_GS13_Stage_Tilted_2012_03_29.mat

**Figures in SVN at:**
SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/Figures/Spectra/Undamped
- LHO_ISI_UNIT_2_m_PSD_GS13_Tilted_2012_03_29.fig

The figure below presents the GS13 power spectrum when the table is unlocked and loaded with a 10Kg mass at each of its corner.

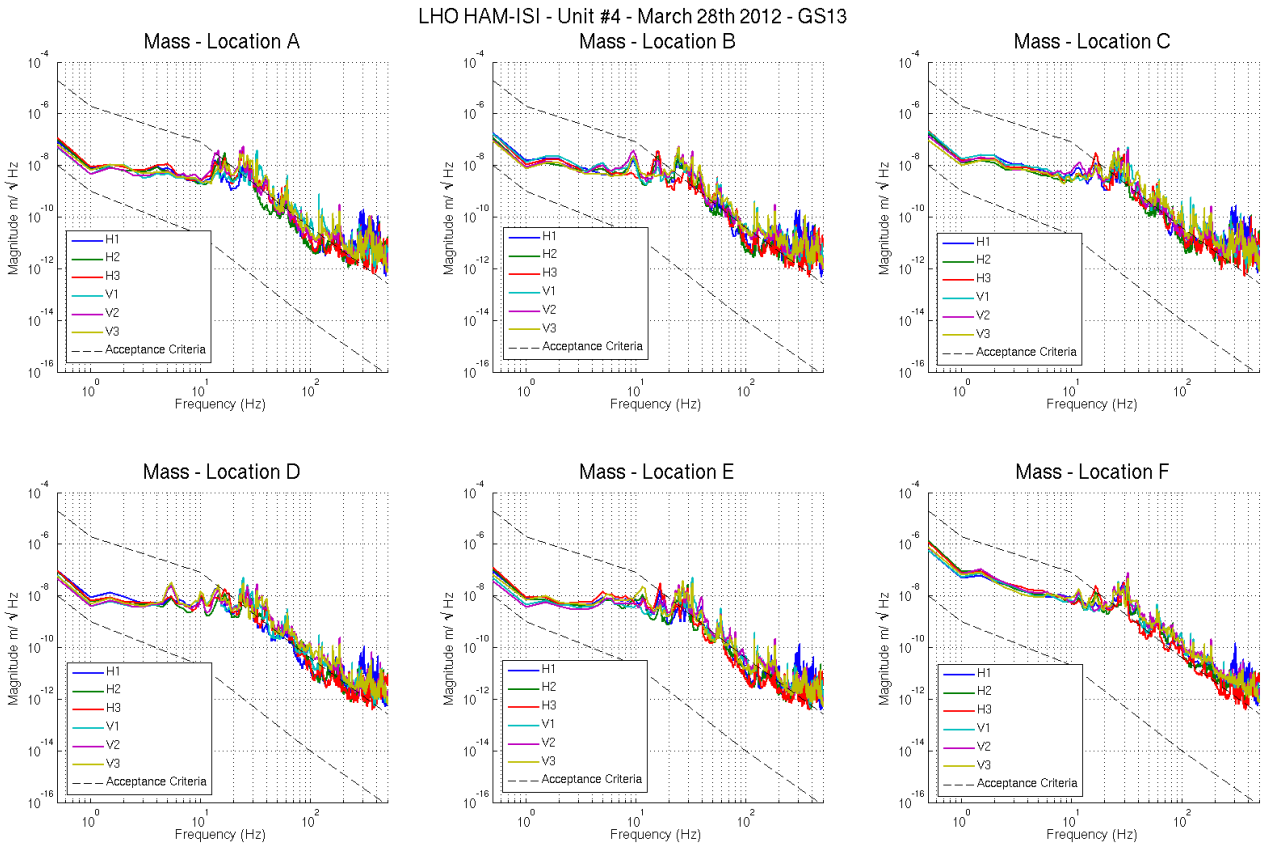



**Figure – Power spectrum Calibrated GS13 with mass at corners A to F**

**Acceptance criteria:**
- With table unlocked and tilted, magnitudes of power spectra must be fully included within requirement curves.

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

**Note:**
When a seismometer fails, its low frequency response is affected. Spectra are within requirements in low frequency. The GS13s installed on this unit are functional.

- ***Step 8- GS13 pressure readout***

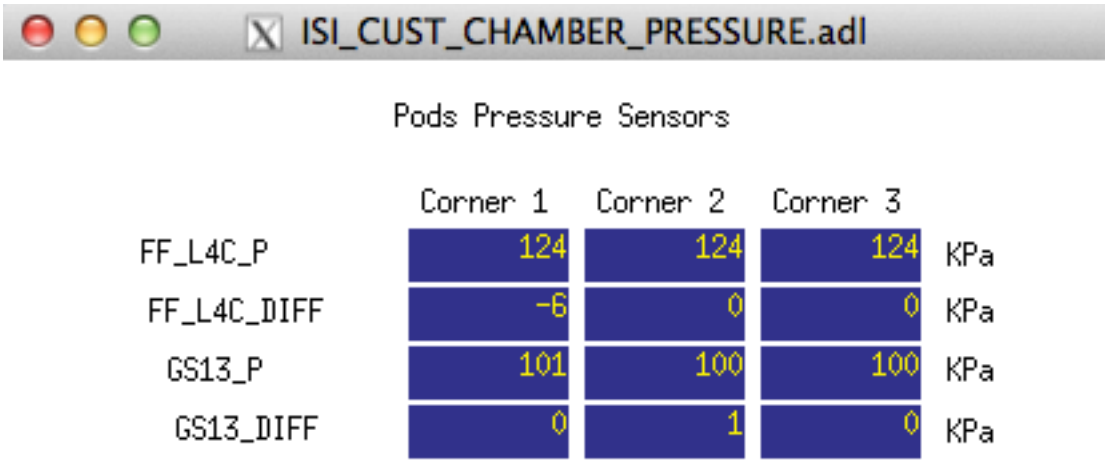



**Figure – Pressure Readouts**

**Acceptance criteria:**
- The pressure on *GS13_P* channels must be 102KPa +/-8 KPa (25000 counts +/- 3000 counts)
- *GS13_P* must vary the same way in each corner and *GS13_DIFF* must be constant (channels follow comparable trend)

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

**Note:** There is no L4C on this Unit. The values read on the FF_L4C_P channels are suspicious. These channels display 30KPa when GS13 interface-chassis are OFF, and 124KPa when GS13 interface chassis are ON.

- ***Step 9 - Coil Driver, cabling and resistance check***

| Actuator | V1 | | H1 | | V2 | |
|---|---|---|---|---|---|---|
| Coil driver | S1000266 - Coarse 2 | | S1000266 - Coarse 1 | | S1000269 - Coarse 2 | |
| Cable # | S1104760 | | S1104762 | | S1104773 | |
| Resistance | P1 - P2 | P2 - P3 | P1 - P2 | P2 - P3 | P1 - P2 | P2 - P3 |
| (Ohm) | O.L (infinity) | 6.3 | O.L (infinity) | 6.4 | O.L (infinity) | 6.6 |
| MEDM offset | Measurement P2 (+) ; P1&P3 (-) | | Measurement P2 (+) ; P1&P3 (-) | | Measurement P2 (+) ; P1&P3 (-) | |
| (1000 counts) | 0.3070V | | 0.3117V | | 0.3115V | |

| Actuator | H2 | | V3 | | H3 | |
|---|---|---|---|---|---|---|
| Coil driver | S1000269 - Coarse 1 | | S1102692 - Coarse 2 | | S1102692 - Coarse 1 | |
| Cable # | S1104776 | | S1104494 | | S1104493 | |
| Resistance | P1 - P2 | P2 - P3 | P1 - P2 | P2 - P3 | P1 - P2 | P2 - P3 |
| (Ohm) | O.L (infinity) | 6.5 | O.L (infinity) | 6.7 | O.L (infinity) | 6.7 |
| MEDM offset | Measurement P2 (+) ; P1&P3 (-) | | Measurement P2 (+) ; P1&P3 (-) | | Measurement P2 (+) ; P1&P3 (-) | |
| (1000 counts) | 0.3138V | | 0.3044V | | 0.3106V | |

**Table - Actuators resistance check**

Issues/difficulties/comments regarding this test:

- Voltages measured from Pin #2 (+) to pin #3 (-) with compensation filters engaged.

**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 #3 (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 #1 (right pin of the plug)
- All LEDs on the coil driver front panel must be green

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

- ***Step 10 - Actuators Sign and range of motion (Local drive)***

| | Negative drive | No Drive | Positive drive | ROM (Counts) |
|---|---|---|---|---|
| H1 readout (count) | -23447 | -149 | 24332 | 47779 |
| H2 readout (count) | -22527 | 47 | 23879 | 46406 |
| H3 readout (count) | -23930 | 85 | 24914 | 48844 |
| V1 readout (count) | -18733 | 198 | 20186 | 38919 |
| V2 readout (count) | -24586 | 69 | 25926 | 50512 |
| V3 readout (count) | -22314 | -93 | 21033 | 43347 |

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

Issues/difficulties/comments regarding this test:

- Compensation filters are ON.

**Acceptance criteria:**

- Main couplings sensors readout must be at least 16000 counts (~0.02")
- 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 - Vertical Sensor Calibration***

| Lockers | D.I readout with for a negative drive | D.I readout without any drive | D.I readout with for a positive drive |
|---|---|---|---|
| **A** | -3.10 | 0.00 | 3.20 |
| **B** | -3.10 | 0.00 | 3.20 |
| **C** | -2.90 | 0.00 | 3.40 |
| **D** | -3.00 | 0.00 | 3.20 |
| **Average** | -3.03 | 0.00 | 3.25 |

| Sensors | Counts | Counts | Counts | Difference |
|---|---|---|---|---|
| **V1** | -2799.40 | -8.99 | 2634.60 | 5434.00 |
| **V2** | -2370.80 | 268.89 | 2910.80 | 5281.60 |
| **V3** | -2106.00 | 583.66 | 3112.40 | 5218.40 |

| Vertical Sensibility | |
|---|---|
| 846.43 | **Count/mil** |
| 0.52 | **V/mil** |
| 30.01 | **nm/count** |
| 0.77 | **% from ref (840count/mil)** |

**Table - Calibration of capacitive position sensors**

**Acceptance criteria:**

- Deviation from nominal value < 2%. Nominal value is 840 count/mil.

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

- ***Step 12 - Vertical Spring Constant***

Results presented below are obtained after the initial sensors calibration.

| Sensors | Mean diff counts | Mean diff m | K (N/m) | Error with average |
|---|---|---|---|---|
| **V1** | -7965 | -2.405E-04 | 83243 | 0.03% |
| **V2** | -7825 | -2.363E-04 | 84733 | 1.82% |
| **V3** | -8118 | -2.451E-04 | 81680 | -1.85% |
| | | Average (N/m) | 249657 | |
| | | | **1.06** | **% variation from nominal** |

**Table - Vertical spring constant**

**Acceptance criteria:**

- +/-2 % of 2.4704e5 N/m (i.e. between 2.421e5 and 2.520e5 N/m)
- +/- 5% of variation between each spring and the average

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

- ***Step 13 - Static Testing (Tests in the local basis)***

| | Sensors (counts) | | | | | |
|---|---|---|---|---|---|---|
| | **H1** | **H2** | **H3** | **V1** | **V2** | **V3** |
| **H1** | 2055 | 1248 | 1239 | 66 | -42 | 51 |
| **H2** | 1272 | 1981 | 1204 | 52 | -62 | 27 |
| **H3** | 1266 | 1211 | 1968 | 63 | -63 | 17 |
| **V1** | 205 | 190 | -362 | 1462 | -43 | -615 |
| **V2** | -390 | 147 | 130 | -568 | 1397 | 5 |
| **V3** | 200 | -361 | 216 | -48 | -626 | 1456 |

**Table - Main couplings and cross couplings**

**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: X** **Failed: ___**

- ***Step 14 - Linearity test***

| | Slope | Offset | Average slope | Variation from average(%) |
|---|---|---|---|---|
| **H1** | 2.0644 | -85.0814 | 2.04 | 1.19 |
| **H2** | 2.0238 | 146.6449 | | -0.80 |
| **H3** | 2.0321 | 202.2433 | | -0.39 |
| **V1** | 1.472 | -171.4327 | 1.46 | 1.10 |
| **V2** | 1.4417 | -163.3527 | | -0.98 |
| **V3** | 1.4542 | -373.6469 | | -0.12 |

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

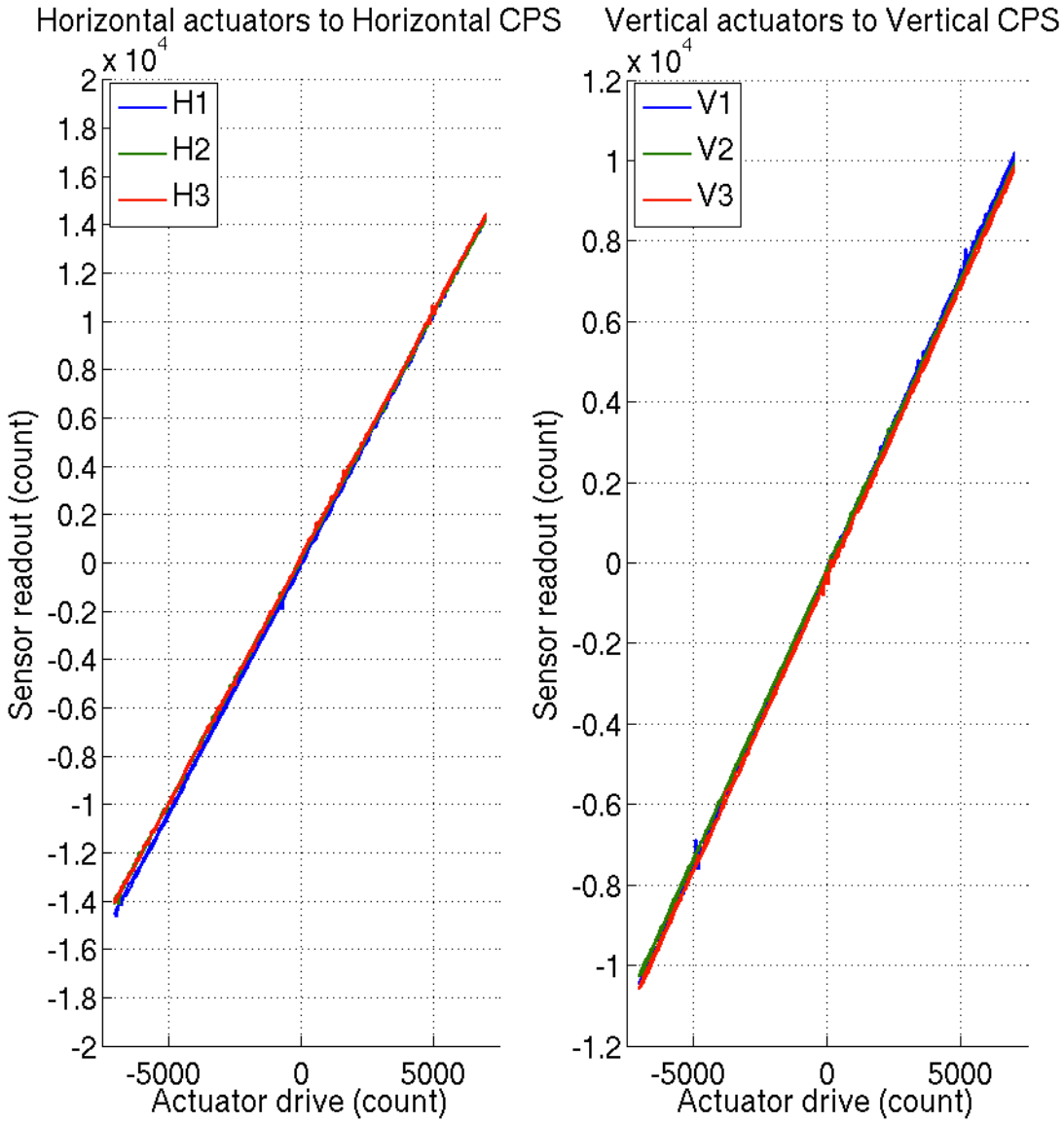



**Figure - Linearity test on the triplet 'actuators - HAM-ISI – sensors' in both Horizontal and vertical directions**

Issues/difficulties encountered during this test:

- H1, V1 do not meet our requirements.
- The tendencies on linearity test slopes seem to match the tendencies on cable resistance (coildriver to feedthrough section). Cable resistance, which is proportional to cable length, would then be a possible explanation for the linearity results obtained.

**Acceptance criteria:**

- Horizontal and vertical slopes of the triplet actuators x HAM-ISI x sensors: Average slope +/- 1%

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

**Note:** we will check that these values are within tolerance when we'll use the final field cables.

- ***Step 15 - Cartesian Basis Static Testing***

| 1000 counts Drive | H1 | H2 | H3 | V1 | V2 | V3 | Direction read out |
|---|---|---|---|---|---|---|---|
| **X Drive** | 293.13 | 286.81 | -454.26 | -44.001 | 6.366 | -0.96136 | 502.32 |
| **Y Drive** | -456.74 | 431 | -15.092 | -17.144 | -5.8459 | -0.18086 | 496.37 |
| **Z Drive** | 7.0322 | 25.939 | 29.914 | 232.42 | 282.87 | 257.66 | 250.97 |
| **Rx Drive** | -463.14 | 467.37 | 2.3234 | -482.97 | 1649.4 | -1198.8 | 2552.3 |
| **Ry Drive** | -280.17 | -243.86 | 550.78 | -1719.1 | 427.7 | 1251.1 | 2640.8 |
| **Rz Drive** | -1965.6 | -1916.4 | -1897.3 | -47.795 | 16.935 | -8.6248 | 2451.7 |

| 1000 counts Drive | H1 | H2 | H3 | V1 | V2 | V3 | Direction read out |
|---|---|---|---|---|---|---|---|
| **X Drive** | + | + | - | | | | + |
| **Y Drive** | - | + | 0 | | | | + |
| **Z Drive** | | | | + | + | + | + |
| **Rx Drive** | | | | - | + | - | + |
| **Ry Drive** | | | | - | + | + | + |
| **Rz Drive** | - | - | - | | | | + |

| 1000 counts Drive | X | Y | Z | RX | RY | RZ | Direction read out |
|---|---|---|---|---|---|---|---|
| **X Drive** | 502.32 | -8.1547 | -15.395 | 36.39 | 36.015 | -35.356 | 502.32 |
| **Y Drive** | -5.7376 | 496.37 | -2.4892 | -9.5645 | 8.2132 | 14.818 | 496.37 |
| **Z Drive** | -8.1221 | -12.01 | 250.97 | 26.351 | 20.255 | -23.686 | 250.97 |
| **Rx Drive** | 5.5059 | 1.4196 | -13.343 | 2552.3 | -0.24508 | -0.63228 | 2552.3 |
| **Ry Drive** | -3.8015 | 8.1816 | -15.553 | 35.745 | 2640.8 | -21.571 | 2640.8 |
| **Rz Drive** | -15.569 | 11.632 | -20.424 | 60.594 | 60.551 | 2451.7 | 2451.7 |

**Table – Cartesian static testing reference table**

**Acceptance criteria:**
For a positive drive in the Cartesian basis:

- Local sensor readout must have the same sign that the reference table
- Cartesian sensors read out must be positive in the drive direction

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

- ***Step 16- Frequency response***
- ***Step 16.1 - Local to local measurements***

| FREQ. RANGE | | | DRIVE | | MEAS. TIME | | |
|---|---|---|---|---|---|---|---|
| Min | Max | Freq. Res. (Hz) | H | V | Time for 1 Rep. (s) | Number of Reps | Time (min) |
| 0.01 | 0.1 | 0.01 | 10500 | 10500 | 620.0 | **4** | 41.3 |
| 0.1 | 0.5 | 0.02 | 600 | 600 | 320.0 | **8** | 42.7 |
| 0.5 | 5 | 0.025 | 35 | 35 | 260.0 | **16** | 69.3 |
| 5 | 200 | 0.1 | 300 | 300 | 80.0 | **40** | 53.3 |
| 200 | 1000 | 0.2 | 135 | 135 | 50.0 | **90** | 75.0 |
| | | | | | Total Meas. Time(h) | | **4.7** |

**Table – Transfer function settings, by frequency band**

**Data files in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/Transfer_Functions/Measurements/Undamped/
- LHO_ISI_HAM_Unit_4_Data_TF_L2L_10mHz_100mHz_20120404-004535.mat
- LHO_ISI_HAM_Unit_4_Data_TF_L2L_100mHz_500mHz_20120403-220357.mat
- LHO_ISI_HAM_Unit_4_Data_TF_L2L_500mHz_5Hz_20120403-181422.mat
- LHO_ISI_HAM_Unit_4_Data_TF_L2L_5Hz_200Hz_20120403-172049.mat
- LHO_ISI_HAM_Unit_4_Data_TF_L2L_200Hz_1000Hz_20120403-160314.mat

**Data collection script files:**
/SeiSVN/seismic/HAM-ISI/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/HAM-ISI/X1/HAMX/Scripts/Control_Scripts/
- Step_1_TF_Loc_to_Loc_X1_ISI_HAMX

**Figures in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/ Figures/Transfer_Functions/Measurements/Undamped/
- X1_ISI_HAMX_TF_L2L_Raw_from_ACT_to_GS13_2012_04_04.fig
- X1_ISI_HAMX_TF_L2L_Raw_from_ACT_to_CPS_2012_04_04.fig

**Storage of measured transfer functions in the SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/Transfer_functions/ Simulations/Undamped/
- LHO_ISI_Unit_2_TF_L2L_Raw_2012_03_10.mat

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

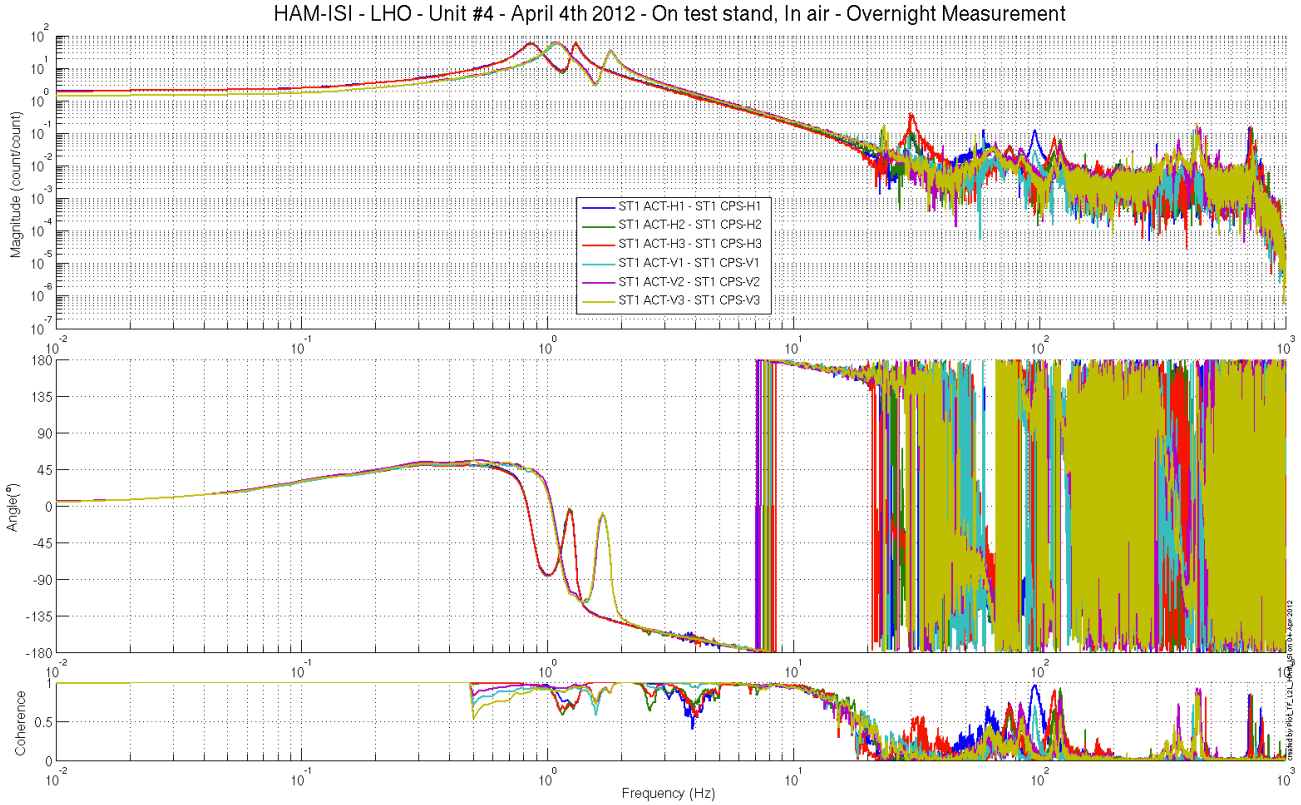



**Figure - local-to-Local Measurements – Capacitive sensors**

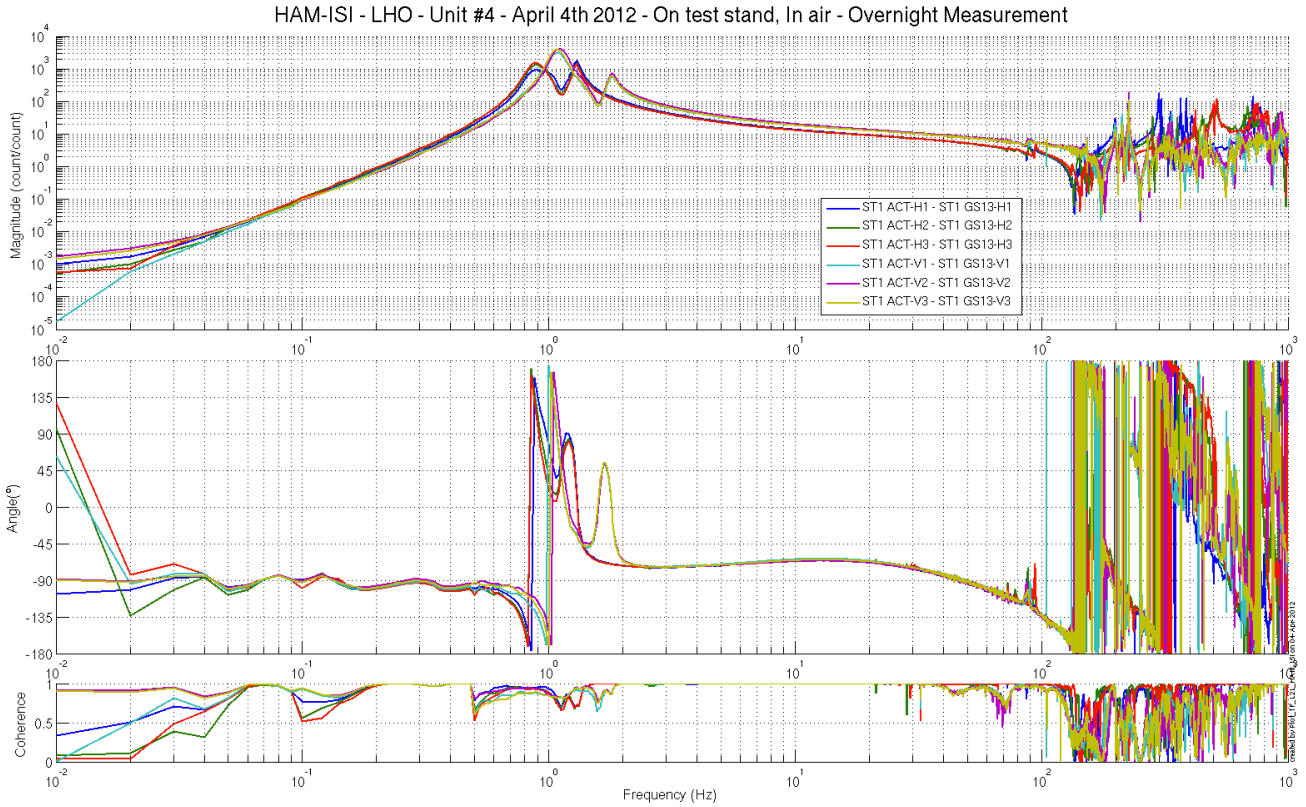



**Figure - local-to-Local Measurements – Inertial sensors**

- ***Step 16.2 - Cartesian to Cartesian measurements***

**Scripts files for processing and plotting in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Scripts/Control_Scripts/

- Step_3_TF_Cart_to_Cart_M1_ISI_HAMX.m

**Figures in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/ Figures/Transfer_Functions/Simulations/Undamped/

- X1_ISI_HAMX_TF_C2C_Symmetrized_from_ACT_to_CPS_2012_04_04.fig
- X1_ISI_HAMX_TF_C2C_Symmetrized_from_ACT_to_GS13_2012_04_04.fig

**Storage of measured transfer functions in the SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/Transfer_functions/Simulations/Undamped/

- X1_ISI_HAMX_TF_C2C_Raw_2012_04_04.mat
-

The Cartesian to Cartesian transfer functions are presented below:

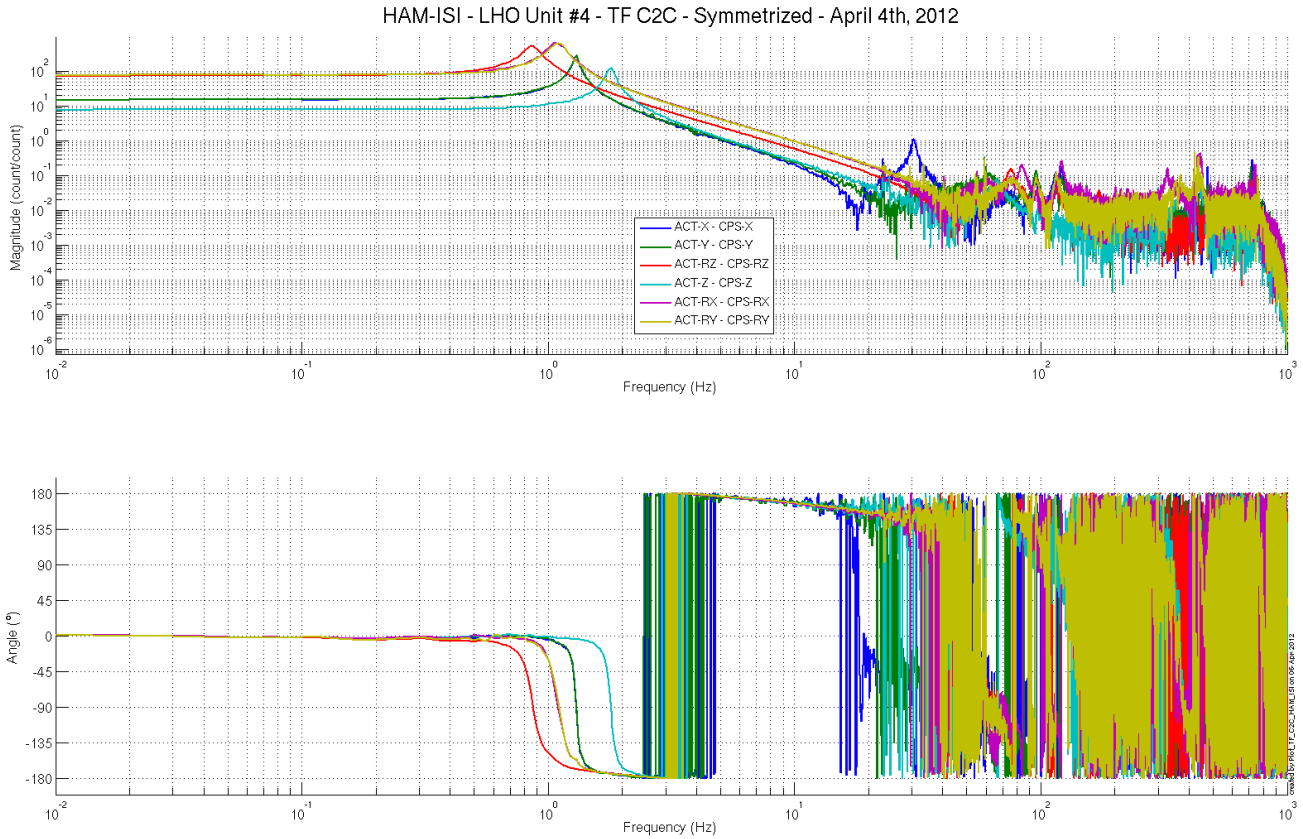



**Figure – Cartesian to Cartesian Measurements – Capacitive sensors**

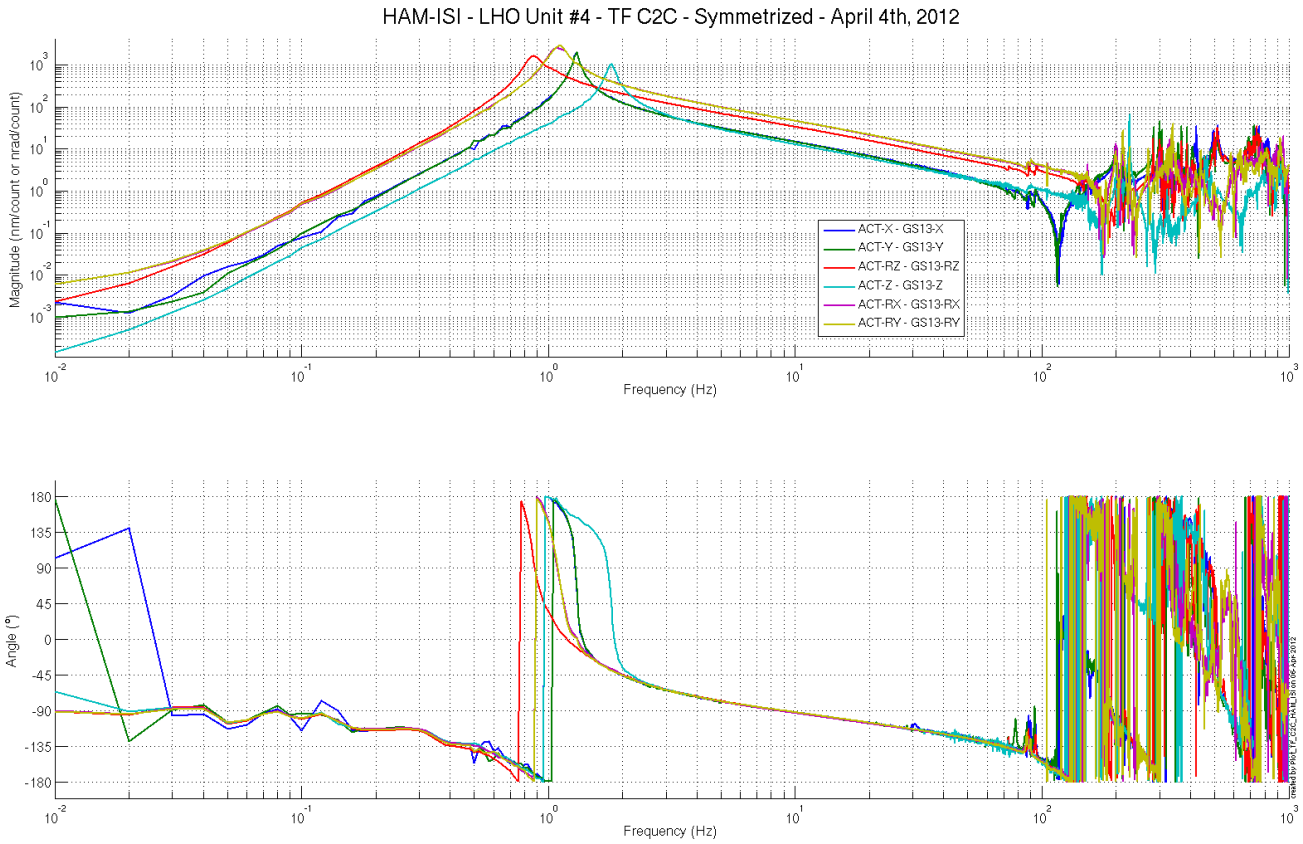



**Figure – Cartesian to Cartesian Measurements – Inertial sensors**

**Acceptance criteria:**

- Local to local measurements
  - On CPS, the phase must be 0º at DC
  - On Geophones, the phase must be -90º at DC
  - Identical shape in each corner
- Cartesian to Cartesian measurements
  - On CPS, the phase must be 0º at DC
  - On Geophones, the phase must be -90º at DC
  - Identical shape X/Y and RX/RY

**Test result:** **Passed: __X__** **Failed: ____**

- ***Step 17 - Transfer function comparison with Reference***

- ***Step 17.1 - Local to local - Comparison with Reference***

**Scripts files for processing and plotting in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Scripts/Control_Scripts/
- Step_1_Plot_TF_L2L_HAM_Testing.m

/SeiSVN/seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Step_1_TF_Loc_to_Loc_X1_ISI_HAMX

**Local to local figures in SVN at:**
/SeiSVN/seismic/ HAM-ISI/X1/HAMX/Data/
Figures/Transfer_Functions/Measurements/Comparisons/L2L/
- X1_ISI_HAMX_TF_L2L_Raw_from_ACT_H_to_CPS_H_vs_UNIT_1_2012_02_02_With_3_Washers_Under_Top_Mass.fig
- X1_ISI_HAMX_TF_L2L_Raw_from_ACT_H_to_CPS_H_vs_UNIT_1_2012_02_02_With_3_Washers_Under_Top_Mass.pdf
- X1_ISI_HAMX_TF_L2L_Raw_from_ACT_H_to_GS13_H_vs_UNIT_1_2012_02_02_With_3_Washers_Under_Top_Mass.fig
- X1_ISI_HAMX_TF_L2L_Raw_from_ACT_H_to_GS13_H_vs_UNIT_1_2012_02_02_With_3_Washers_Under_Top_Mass.pdf
- X1_ISI_HAMX_TF_L2L_Raw_from_ACT_V_to_CPS_V_vs_UNIT_1_2012_02_02_With_3_Washers_Under_Top_Mass.fig
- X1_ISI_HAMX_TF_L2L_Raw_from_ACT_V_to_CPS_V_vs_UNIT_1_2012_02_02_With_3_Washers_Under_Top_Mass.pdf

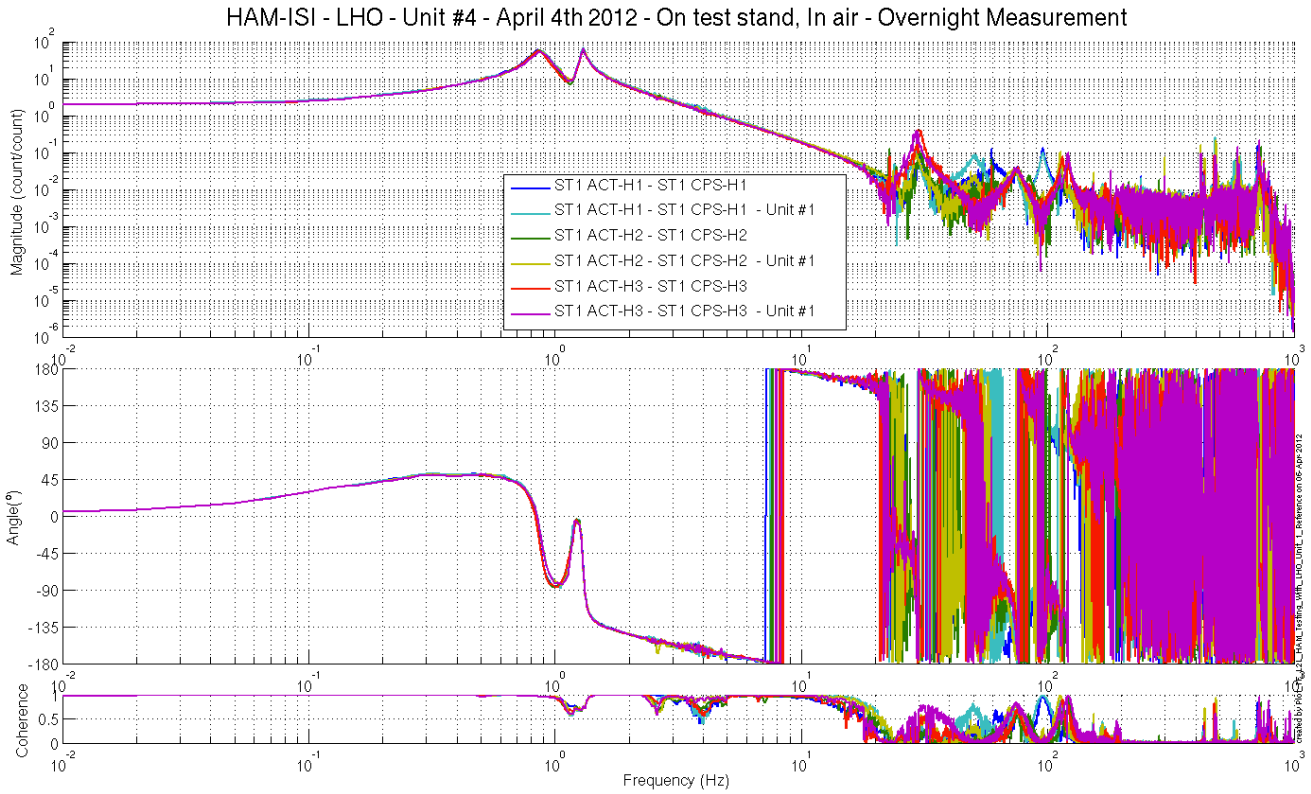



**Figure – local-to-Local measurements, comparison with Unit #1 reference**
**Capacitive Position Sensors - Horizontal motion**

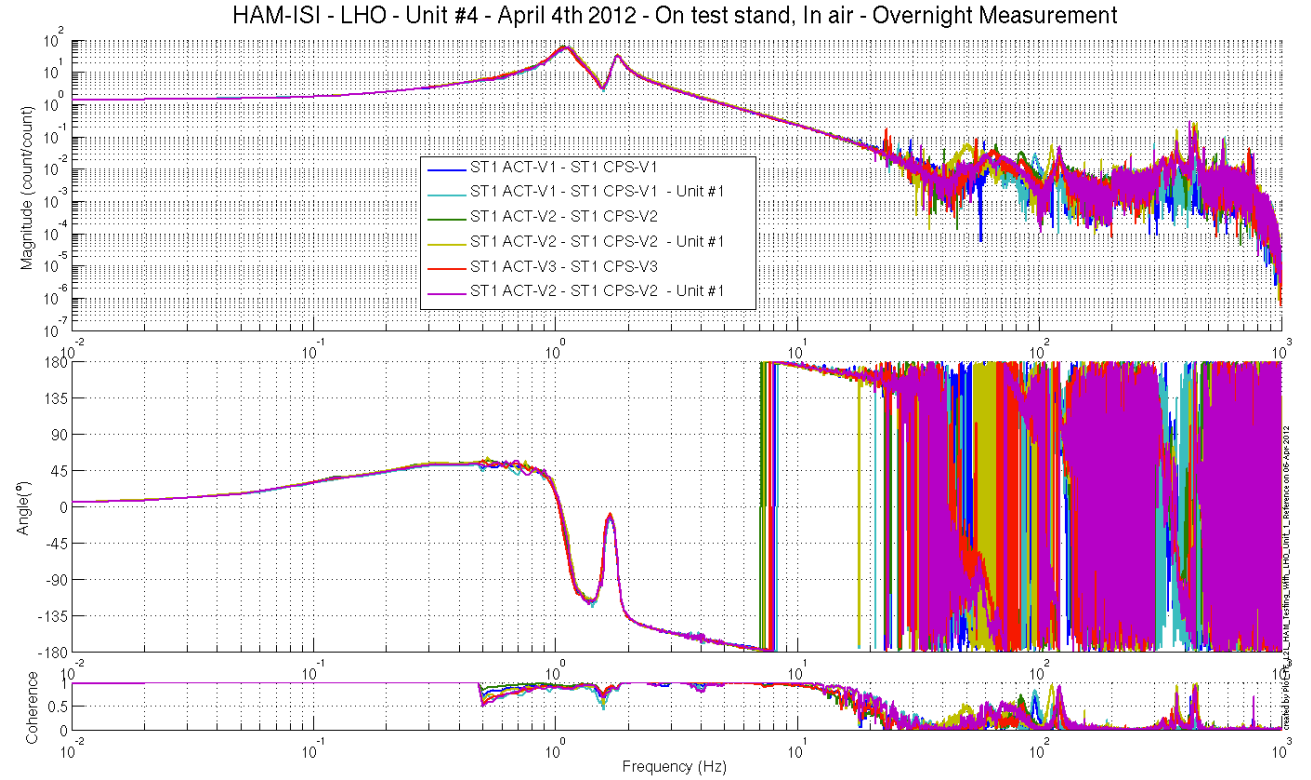



**Figure – local-to-Local measurements, comparison with Unit #1 reference**
**Capacitive Position Sensors - Vertical motion**

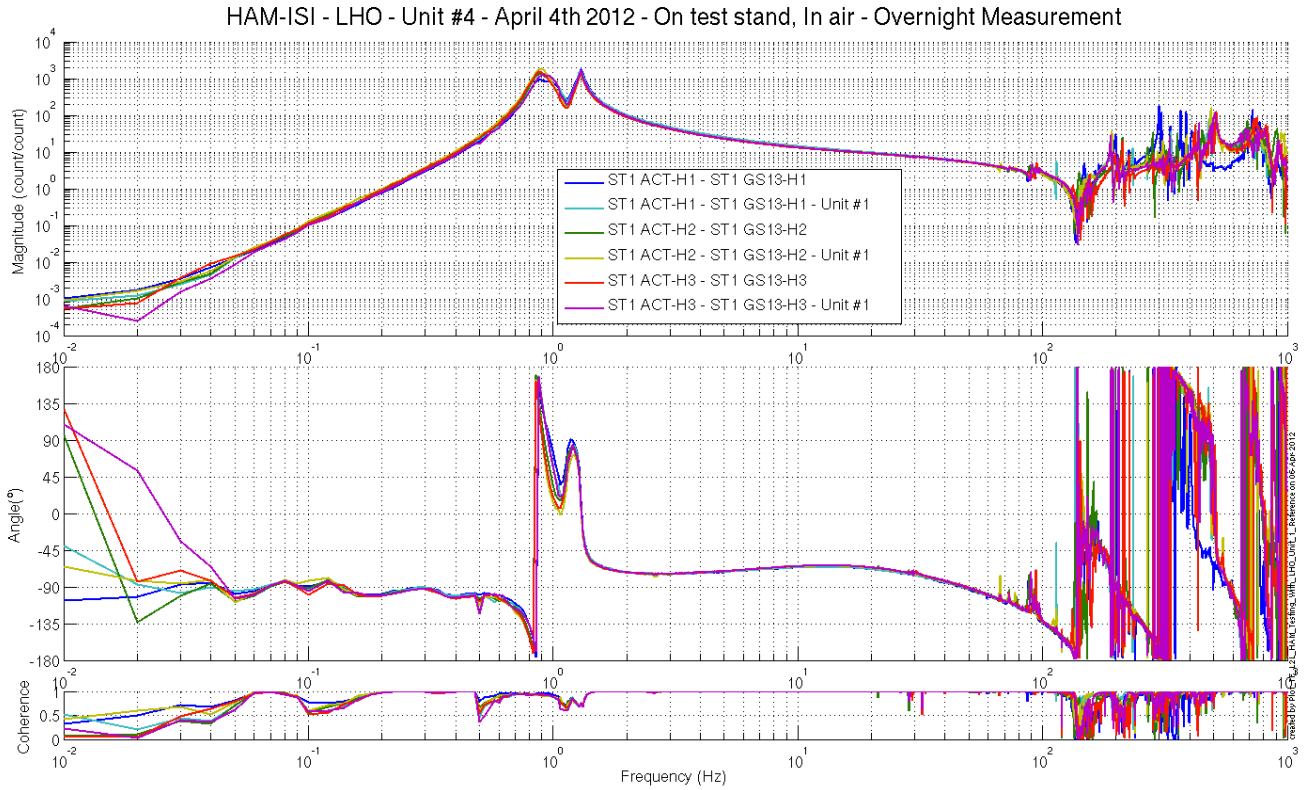



**Figure – local-to-Local measurements, comparison with Unit #1 reference**
**Inertial Sensors - Horizontal motion**

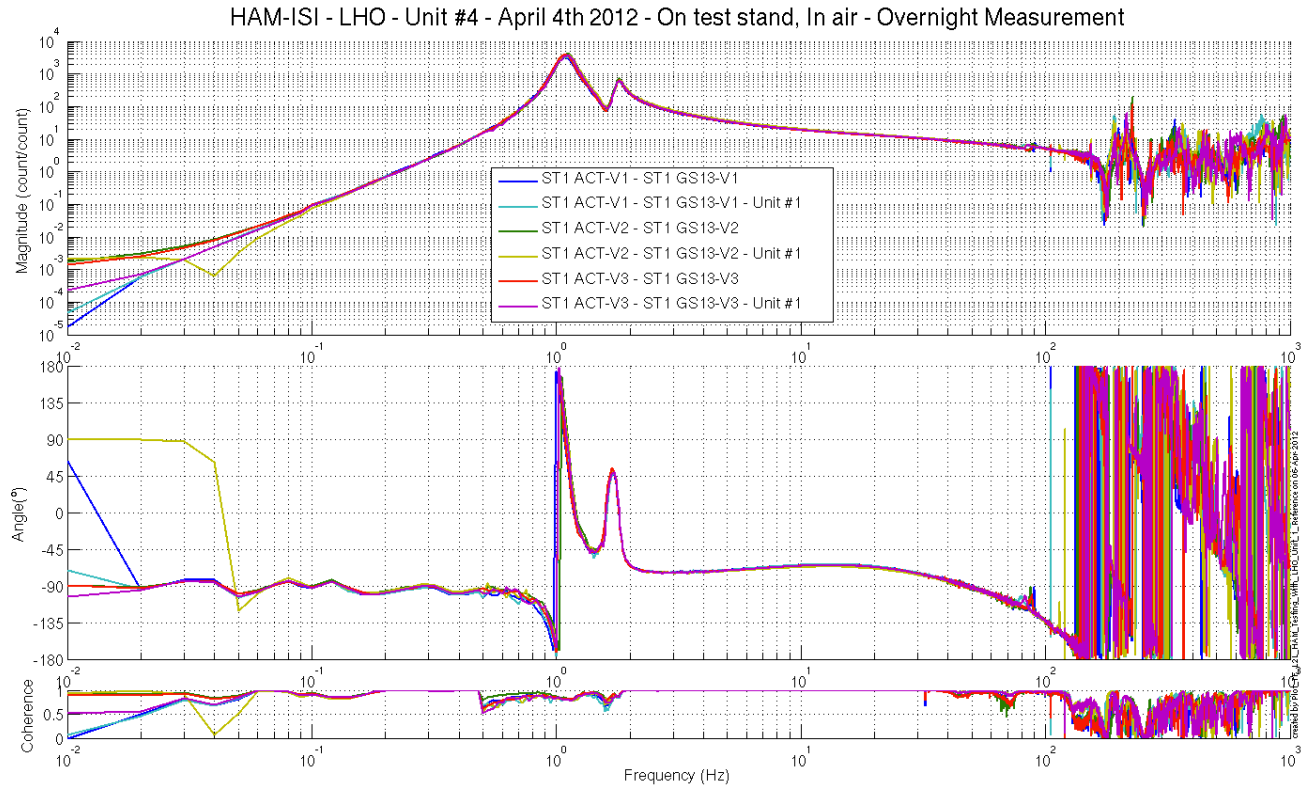



**Figure – local-to-Local measurements, comparison with Unit #1 reference**
**Inertial Sensors - Vertical motion**

- ***Step 17.2 - Cartesian to Cartesian - Comparison with Reference***

**Scripts files for processing and plotting in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Scripts/Control_Scripts/
- Step_3_TF_Cart_to_Cart_M1_ISI_HAMX.m

/SeiSVN/seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Plot_TF_C2C_HAM_Testing_With_LHO_Unit_1_Reference.m

**Cartesian to Cartesian figures in SVN at:**
/SeiSVN/seismic/ HAM-ISI/X1/HAMX/Data/
Figures/Transfer_Functions/Measurements/Comparisons/C2C/
- X1_ISI_HAMX_TF_C2C_Raw_from_ACT_H_to_CPS_H_Symmetrized_vs_Unit_1_2012_04_04.fig
  X1_ISI_HAMX_TF_C2C_Raw_from_ACT_V_to_CPS_V_Symmetrized_vs_Unit_1_2012_04_04.fig
- X1_ISI_HAMX_TF_C2C_Raw_from_ACT_H_to_GS13_H_Symmetrized_vs_Unit_1_2012_04_04.fig
  X1_ISI_HAMX_TF_C2C_Raw_from_ACT_V_to_GS13_V_Symmetrized_vs_Unit_1_2012_04_04.fig

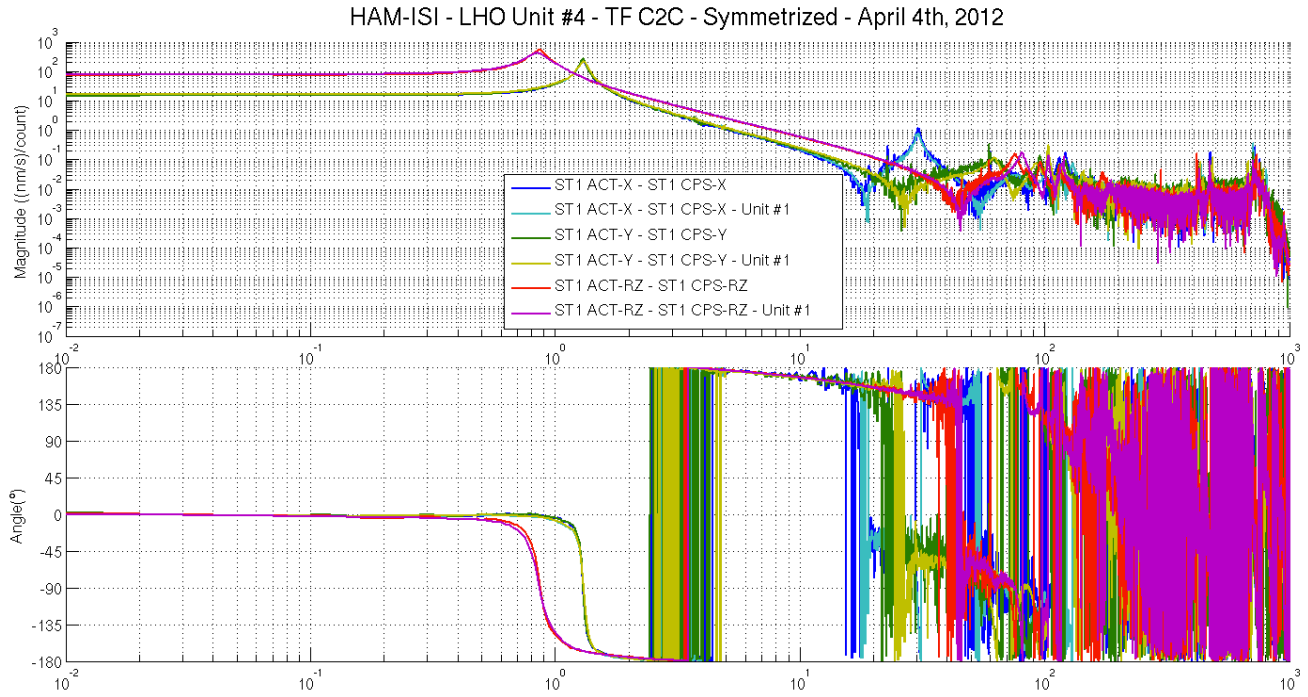



**Figure – Cartesian to Cartesian measurements, comparison with Unit #1 reference**
**Capacitive Position Sensors - Horizontal motion**

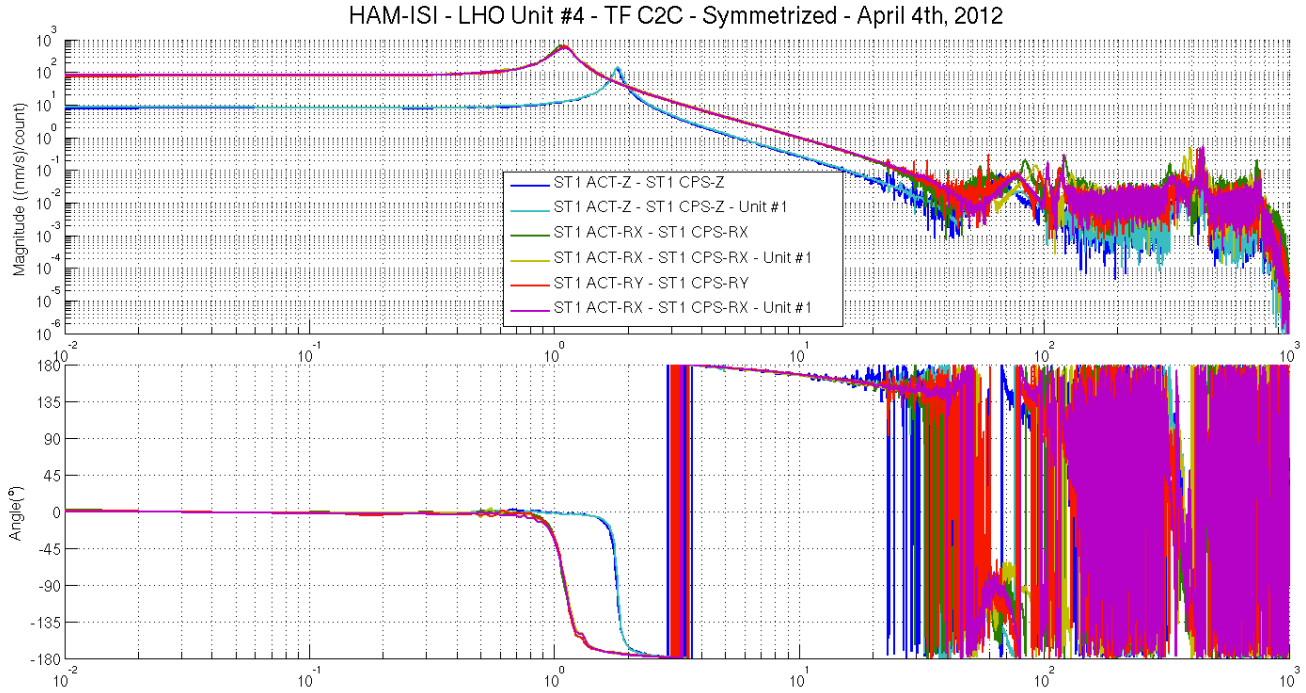



**Figure – Cartesian to Cartesian measurements, comparison with Unit #1 reference**
**Capacitive Position Sensors - Vertical motion**

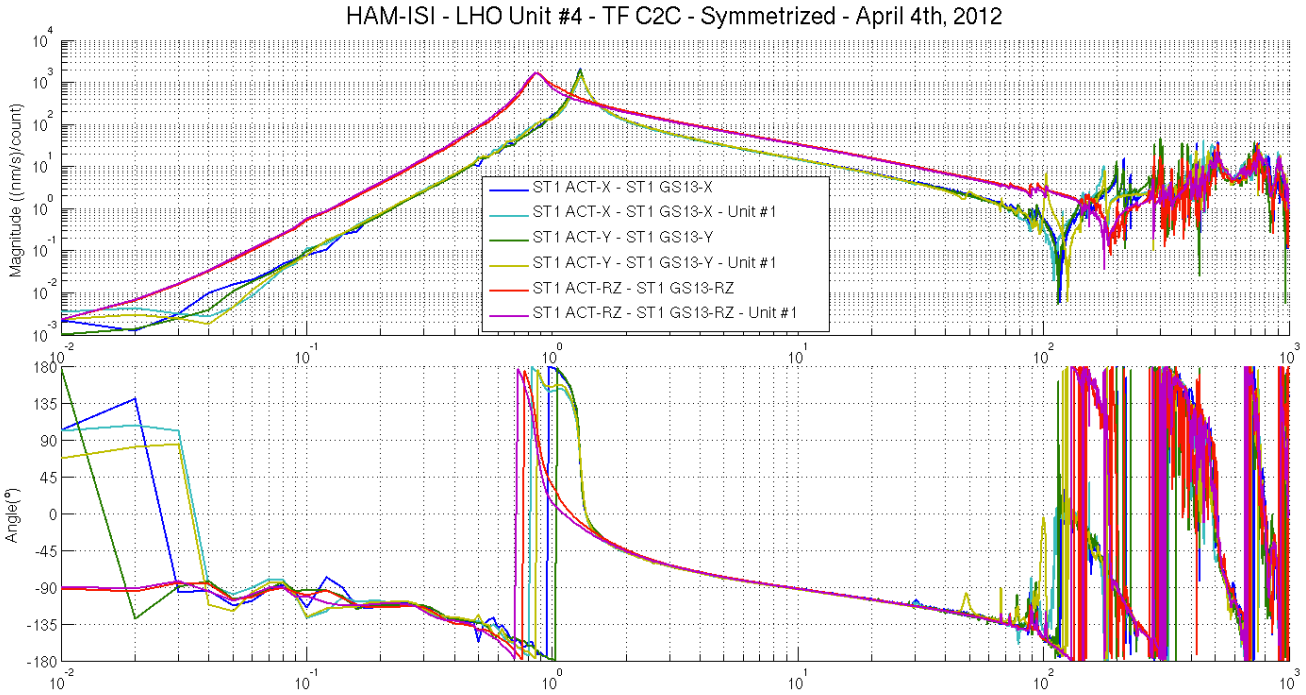



**Figure – Cartesian to Cartesian measurements, comparison with Unit #1 reference – Inertial Sensors**
**Horizontal motion**

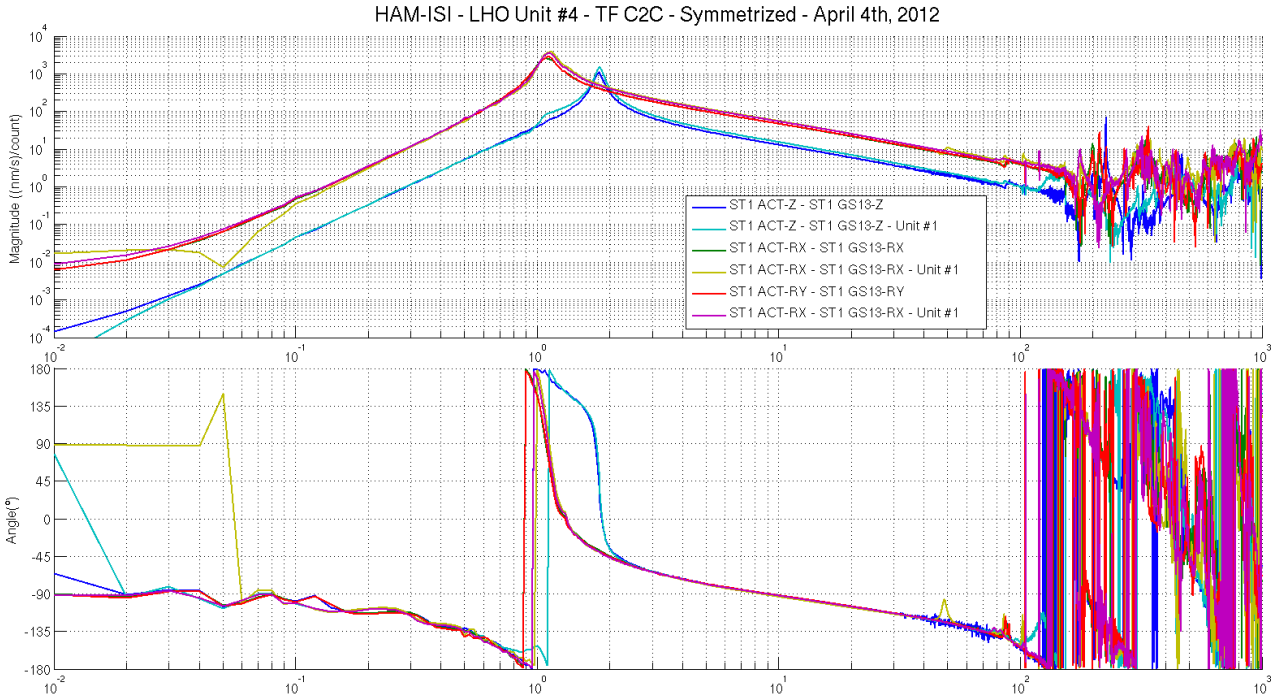



**Figure – Cartesian to Cartesian measurements, comparison with Unit #1 reference**
**Inertial Sensors - Vertical motion**

Issues/difficulties encountered during this test:
Unit #4's Cartesian-TFs were simulated. Coherence is not available.

**Acceptance criteria:**

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

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

- ***Step 18 - Lower Zero Moment Plane***

**Data collection script files:**
/SeiSVN/seismic/HAM-ISI/Common/Transfer_Function_Scripts/
- Run_TF_C2C_10mHz_100mHz_LZMP_HAM_ISI.m

**Data files in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/Transfer_Functions/Measurements/Undamped/
- LHO_ISI_HAM_Unit_4_Data_TF_C2C_10mHz_100mHz_LZMP_20120404-160818.mat

**Scripts files for processing and plotting in SVN at:**
/SeiSVN/seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- LZMP_HAM_ISI.m

**Figures in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/ Figures/Transfer_Functions/Measurements/Undamped/
- LHO_ISI_UNIT_2_LZMP_20120404.fig

The result of the measurement performed is presented below.

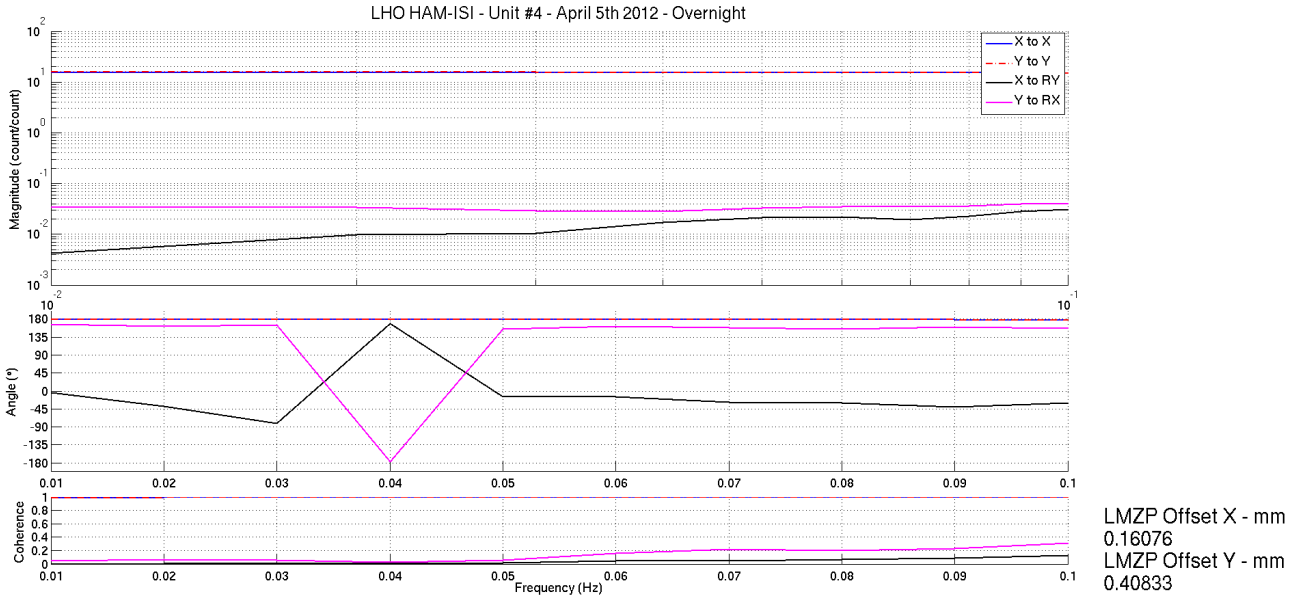



**Figure - Lower Zero Moment Plane – Main and cross couplings at low frequency**

**Acceptance criteria:**
- X offset must be less than 2 mm
- Y offset must be less than 2 mm

**Test result:** **Passed: X** **Failed: ____**

**Note:** Coherence is low on that measurement. More averages were needed.

- ***Step 19 - Damping loops***

In this step, HAM6 damping loops are implemented. First, damping performances are evaluated in simulation. Second, Damping loops are implemented and performance is experimentally measured.

- ***Step 19.1 - Transfer functions - Simulation***

**Continuous HAM6 filters are located in the SVN at:**
/SeiSVN/seismic/HAM-ISI/Common/HAM6_Main_Results/
- HAM6_LLO_Damping_Filters.mat

**Scripts files used to evaluate damping loops performance from measurementsare located in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Scripts/Control_Scripts/
- Step_4_Damping_Filters_X1_ISI_HAMX.m

**TF Data file is located in the SVN at:**
/seismic/HAM-ISI/X2/Data/Unit_2/Transfer_Functions/Simulations/Damping/
- X1_ISI_HAMX_TF_C2C_Damped_2012_04_04.mat

**Figures in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/Figures/Transfer_Functions/Simulations/Damped/
- X1_ISI_HAMX_Damping_TF_MIMO_ST1_ACT_RX_to_ST1_GS13_RX_2012_04_04.fig
  X1_ISI_HAMX_Damping_TF_MIMO_ST1_ACT_Y_to_ST1_GS13_Y_2012_04_04.fig
  X1_ISI_HAMX_TF_Damped_SISO_ACT_RZ_to_GS13_RZ_2012_04_04.fig
- X1_ISI_HAMX_Damping_TF_MIMO_ST1_ACT_RX_to_ST1_GS13_RX_2012_04_04.pdf
- X1_ISI_HAMX_Damping_TF_MIMO_ST1_ACT_RY_to_ST1_GS13_RY_2012_04_04.fig
  X1_ISI_HAMX_Damping_TF_MIMO_ST1_ACT_Z_to_ST1_GS13_Z_2012_04_04.fig
  X1_ISI_HAMX_TF_Damped_SISO_ACT_X_to_GS13_X_2012_04_04.fig
- X1_ISI_HAMX_Damping_TF_MIMO_ST1_ACT_RZ_to_ST1_GS13_RZ_2012_04_04.fig
  X1_ISI_HAMX_TF_Damped_SISO_ACT_RX_to_GS13_RX_2012_04_04.fig
  X1_ISI_HAMX_TF_Damped_SISO_ACT_Y_to_GS13_Y_2012_04_04.fig
- X1_ISI_HAMX_Damping_TF_MIMO_ST1_ACT_X_to_ST1_GS13_X_2012_04_04.fig
  X1_ISI_HAMX_TF_Damped_SISO_ACT_RY_to_GS13_RY_2012_04_04.fig
  X1_ISI_HAMX_TF_Damped_SISO_ACT_Z_to_GS13_Z_2012_04_04.fig

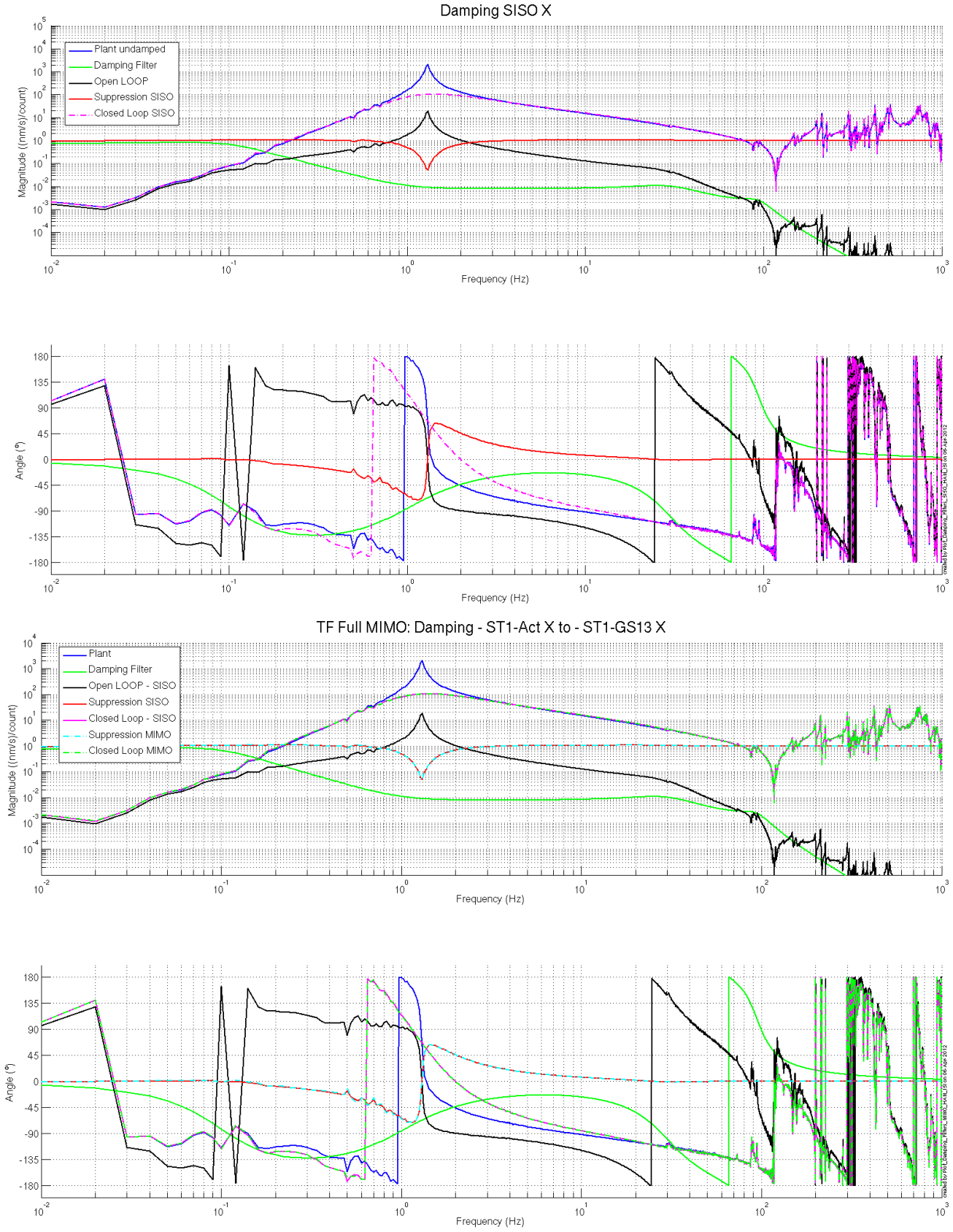



**Figure – Simulated damping performances**

**Acceptance criteria:**

- HAM6 damping loops must implemented and stable with
  - Phase margin must be at least 45º
  - Gain margin must be at least 20dB

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

- ***Step 19.2 - Powerspectra – Experimental***

**Scripts files for taking data and plotting in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/Scripts/Data_Collection/
- Master_TEST_X1_ISI_Unit_4.m (lines 99 to 114)

**Data files in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/Spectra/Damped/
- LHO_ISI_UNIT_4_ASD_m_CPS_GS13_Undamped_vs_Damped_2012_03_16_154951.mat

**Figures in SVN at:**
/SeiSVN/seismic/HAM-ISI/X1/HAMX/Data/Figures/Spectra/Damped/
- LHO_ISI_UNIT_2_ASD_CT_CPS_CART_Undamped_vs_Damped04_04_142551.fig
- LHO_ISI_UNIT_2_ASD_CT_GS13_CART_Undamped_vs_Damped04_04_142551.fig
- LHO_ISI_UNIT_2_ASD_m_CPS_CART_Undamped_vs_Damped04_04_142551.fig
- LHO_ISI_UNIT_2_ASD_m_GS13_CART_Undamped_vs_Damped04_04_142551.fig
- LLO_HAM_ISI_Unit_2_Calibrated_PSD_CPS_Undamped_Damped04_04_142551.fig

Issues/difficulties encountered during this test:
Like for Unit #2, damping was slightly overestimated along Z-axis.

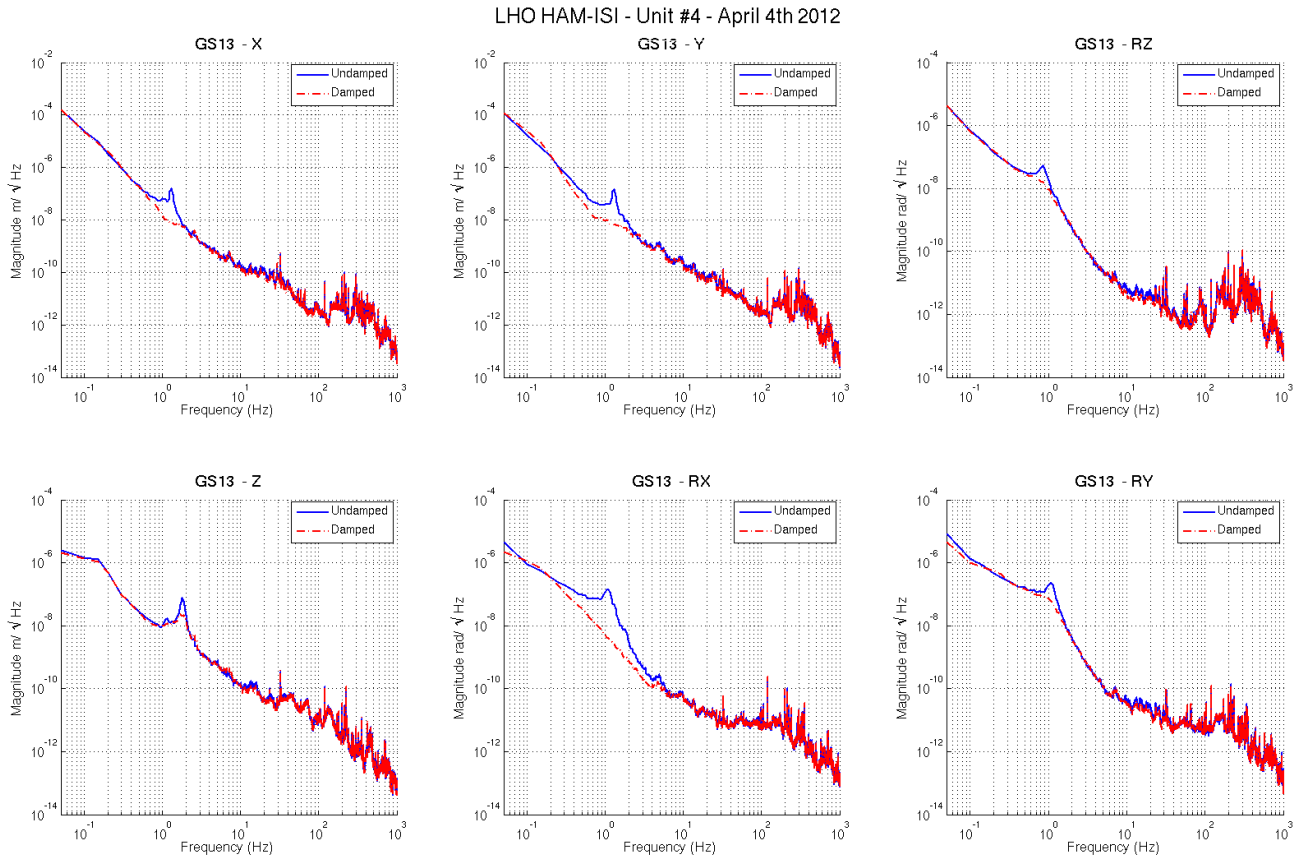



**Figure - Damped/Undamped GS-13 Power Spectra comparison**

**Acceptance criteria:**

- HAM6 damping loop must stable when all damping loops are engaged
- Similar damping effect than in simulated plots

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

# IV. HAM-ISI Unit #4 testing summary

HAM-ISI Unit #4 was built in March 2012. Tests presented here were performed between March 28th 2012 and April 4th 2012. Tests were performed in accordance with E1000309-V9 procedure.

Particularities:
- This Unit received two production GS13s from Unit #2
- This Unit is equipped with a full set of production GS13

Complementary inquiries:
- Effect of washers' disposition/thickness on high frequency unwanted resonances/noise (LHO alog # 2520)

## FAILED AND WAIVED TESTS

- ***List of tests that failed and don't need to be redone:***

**Step III.2**: Excessive standard deviation on CPSs is associated to ground motion (SEI logbook, entry #15). Sensor noise is acceptable.

- ***Tests that failed and need to be done during phase II***

**Step III.14**: Actuators appear to be linear on measurements. However, deviation from average slope is out of spec. It seems to correlate with cable+actuator resistance measurements. Make sure that linearity test results correlate with the final field cables.
This scale factor, which varies from an actuation point to another, could be corrected with an adjustment gain applied on the excitation signal sent to the actuators.

- ***List of test that were skipped and that we will not do because they are not essential***

**Step III.3**: Sensor gap measurement with a jig. Waved to avoid scratching targets. Distance between sensor and target has also been checked during the assembly while adjusting target distance.