LIGO Laboratory / LIGO Scientific Collaboration

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aLIGO HAM-ISI, Installation Test Report, Phase II, LLO HAM 4

E1200103-V3

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Distribution of this document:
Advanced LIGO Project

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Introduction

This document presents the tests performed to characterize and validate the "HAM-ISI LLO Unit #4". This unit was the 4th unit assembled for aLIGO at LLO. This unit was assembled in June and July 2011.

This was the third unit pulled out from storage for installation at Livingston in January 2012, to be installed in HAM 4 chamber. Horizontal seismometers, springs tuned mass dampers, and final cables were installed. Also, the Capacitive Position Sensors cables were shielded.

This document is thought as the follow-up of the previous test document, written after assembly. Only modifications and basic functionalities were tested at this time.

There are 4 distinctive parts:

- Part I: side chamber testing results
- Part II: post insertion testing results
- Part III: Transfer functions taken during optics installation
  - 3.1 transfer functions after first triple install
  - 3.xx ....
- Part IV: Tests in final configuration

I. SIDE CHAMBER TESTING

Side chamber testing was conducted in the LLO LVEA with actual electronics and field cables from May 9th until May 23rd 2012. Temporary extensions to those cables were used to reach the test stand located further away from the electronics than the HAM chamber is.
Steps 1 and 2 capture data from testing done previously, whereas all the following steps were done (or waived) during that side-chamber testing period.

- ***Step 1: 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\

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

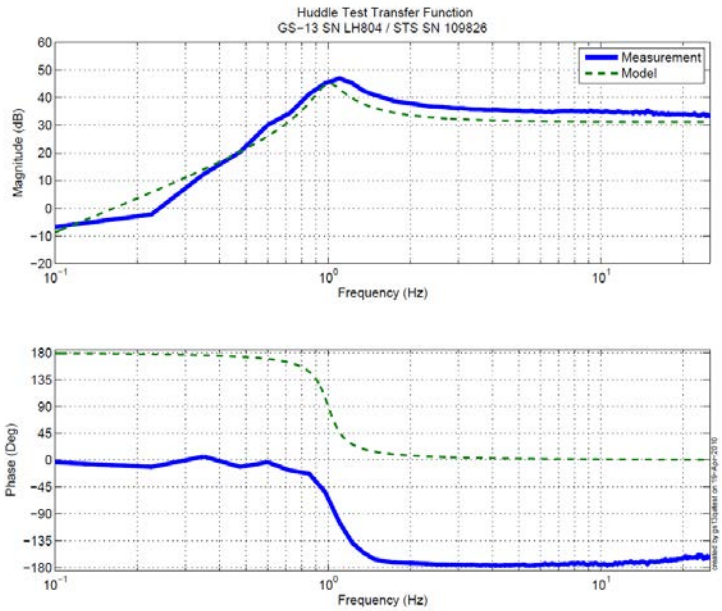
Data files in SVN at:
seismic/Common/Data/aLIGO_GS13_TestData/PostMod_TestResults_RawASCII

Scripts files for processing and plotting in SVN at:
seismic/Common/MatlabTools
- gs13qatest.m

Figures in SVN at:
seismic/Common/Data/aLIGO_GS13_TestData/PostMod_TestResults_PDFs

- ***Step 1.1 – Horizontal GS-13s***

Huddle testing



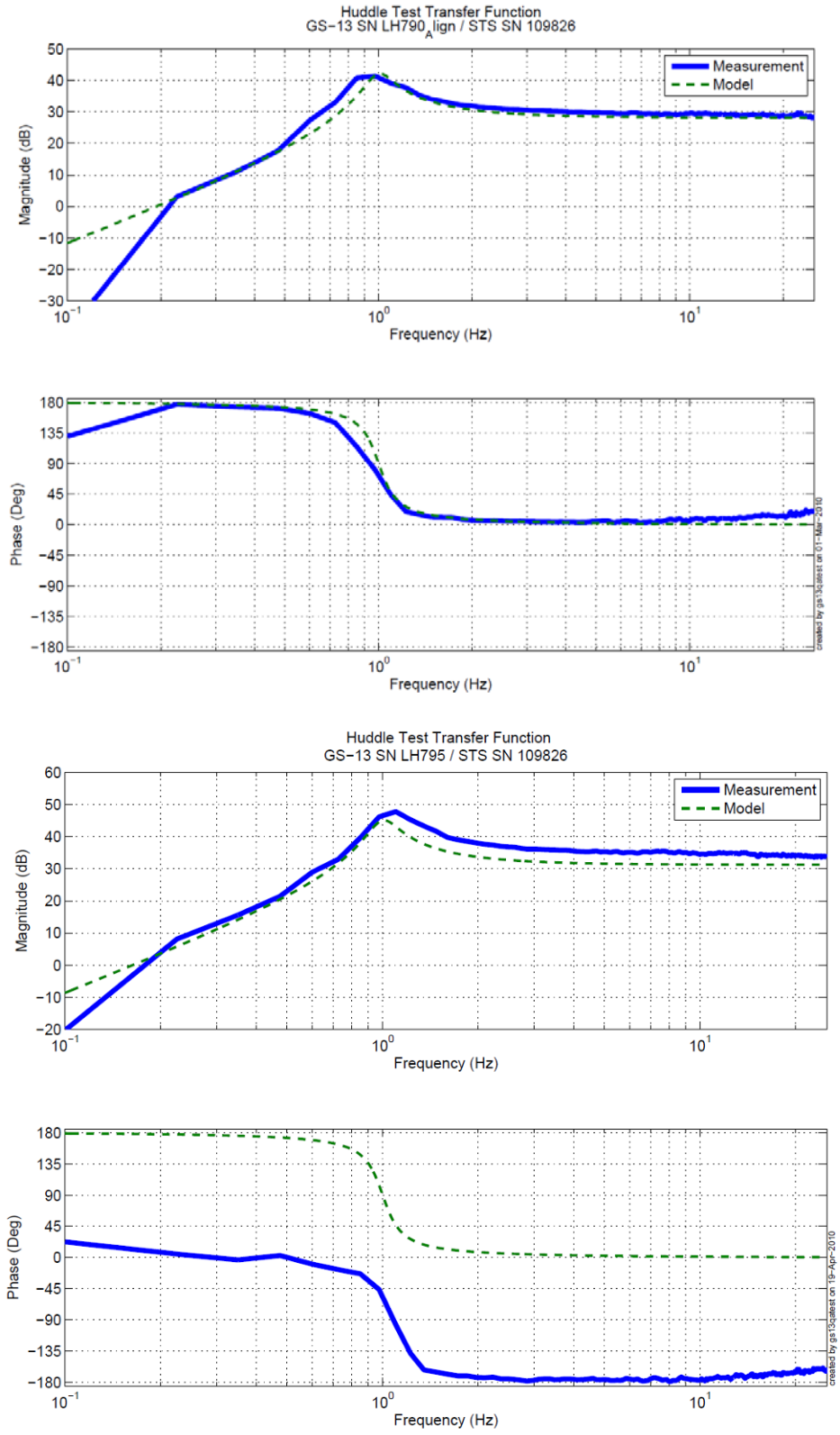


Figure - Huddle testing of Horiz GS-13 804, 790, and 795 after aLIGO modifications

Issues/difficulties/comments regarding this test:
Not all GS-13s have exactly the same resonant frequency. This parameter was adjusted as well as manageable after modifications of the instruments. Instruments were passed as long as their resonant frequencies were within 0.95 and 1.2 Hz.

Some instruments appear out of phase compared to the model. This only means the instrument was placed at 180 deg compared to the expected position when the model was created . This was ignored in order to approve the instrument for use.

Acceptance Criteria

- All instruments match their expected response.

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

- ***Step 2: L4C***

All the data related to L4C post podding testing can be found in the SVN at :
SeismicSVN\seismic\Common\Data\aLIGO_L4C_TestData\.
E1000136 spreadsheet provides the status of each individual L4C at LLO site during aLIGO HAM assembly

Data files in SVN at:
seismic/Common/Data/aLIGO_L4C_TestData/ TestResults_RawASCII

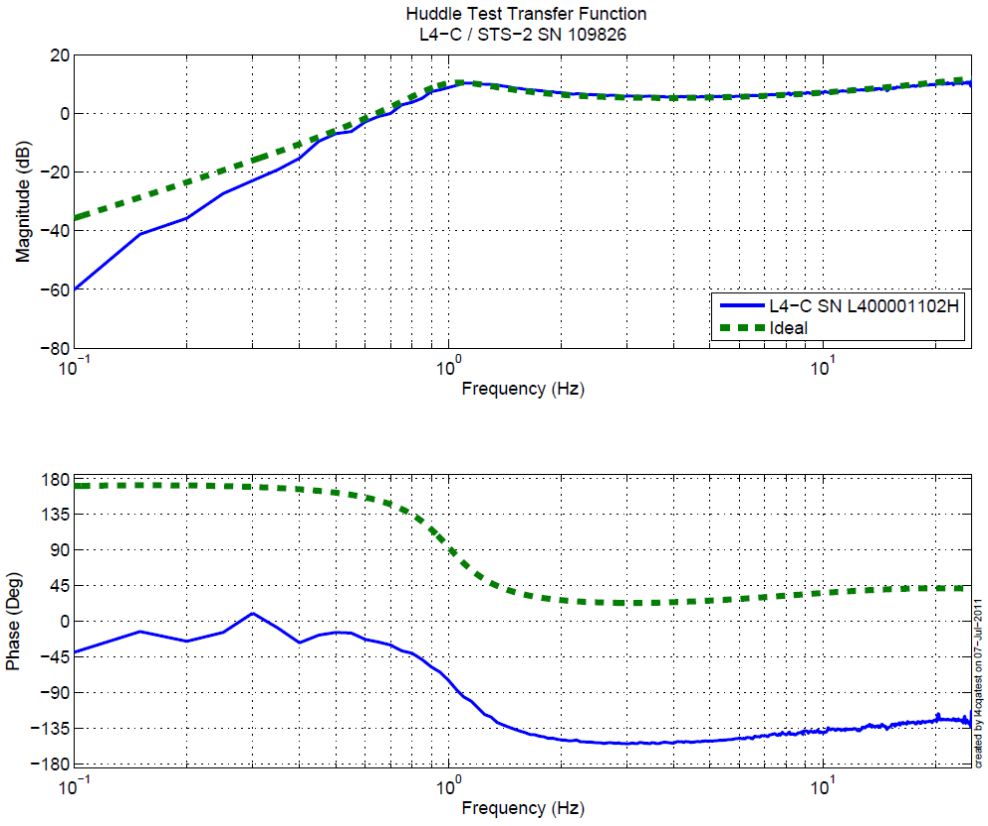
Scripts files for processing and plotting in SVN at:
seismic/Common/MatlabTools

- l4cqatest.m

Figures in SVN at:
seismic/Common/Data/aLIGO_L4C_TestData/ TestResults_PDFs

- ***Step 2.1 – Horizontal L4Cs***

Huddle testing



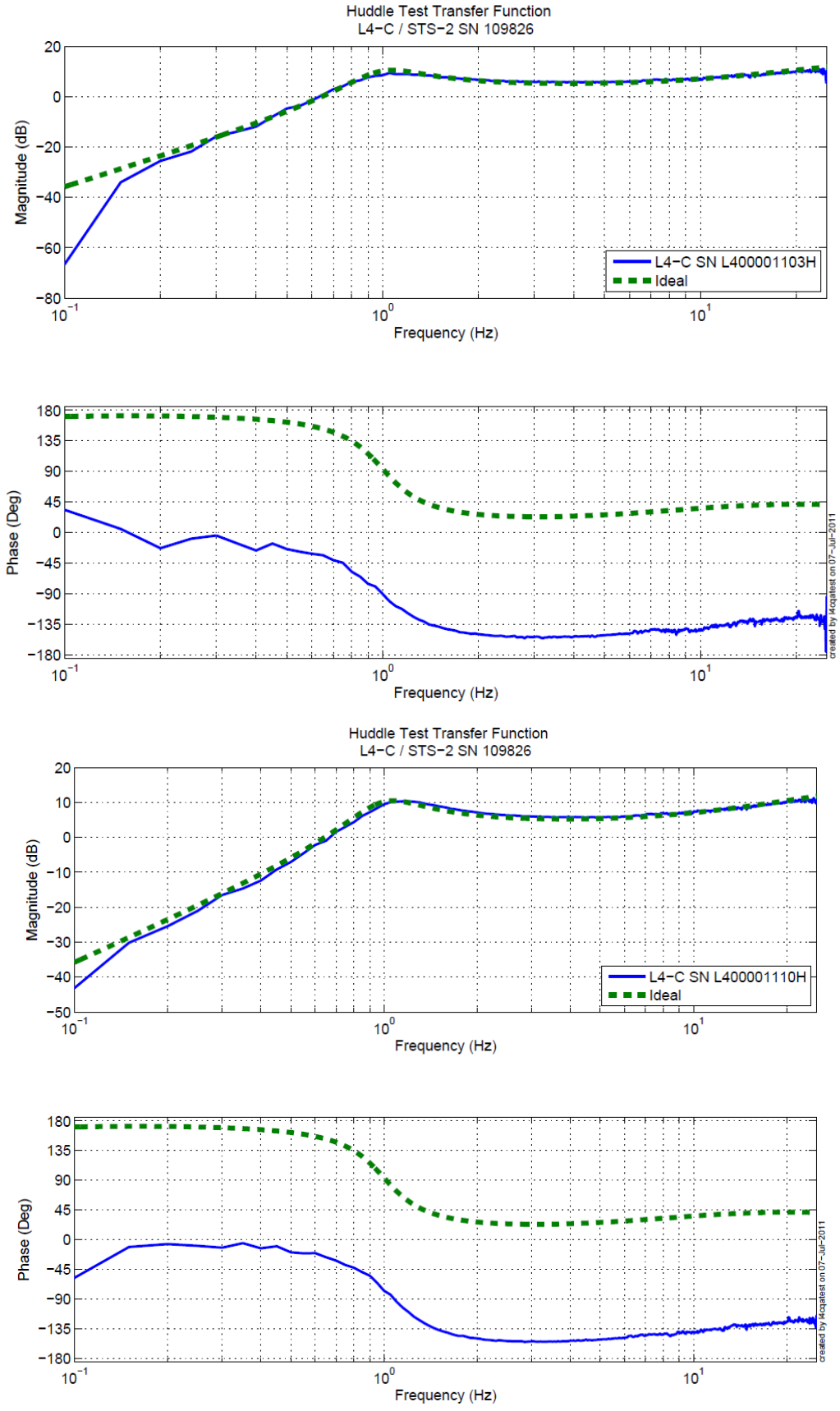
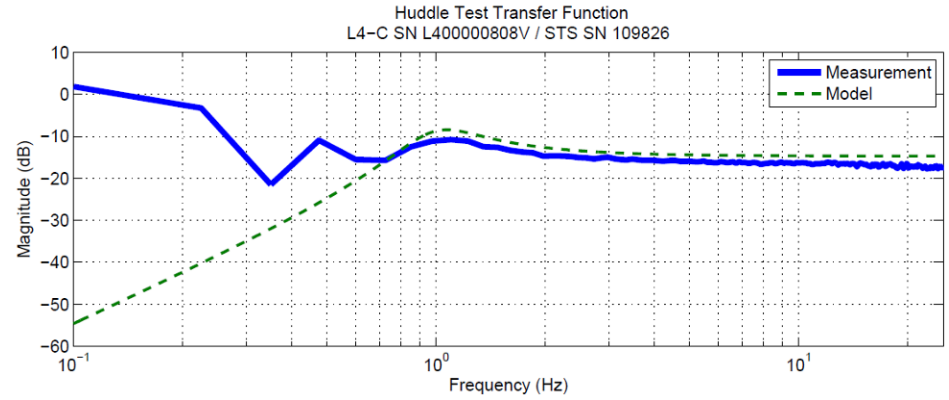
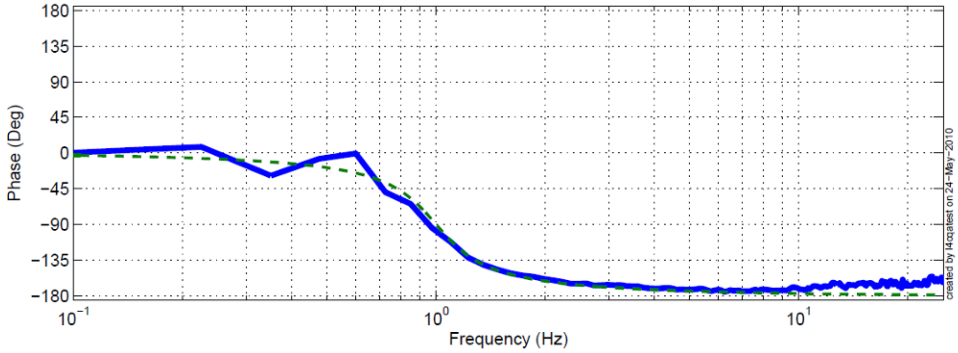


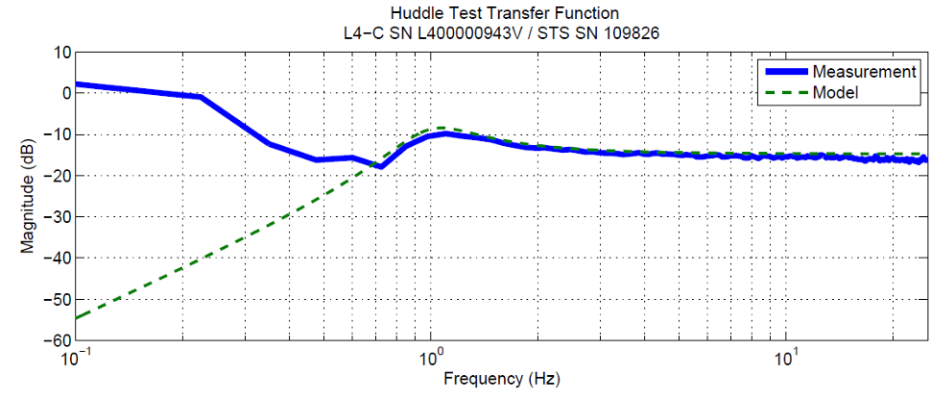
Figure - Huddle testing of Horiz L4-C 1102,1103, and 1110 after aLIGO modifications

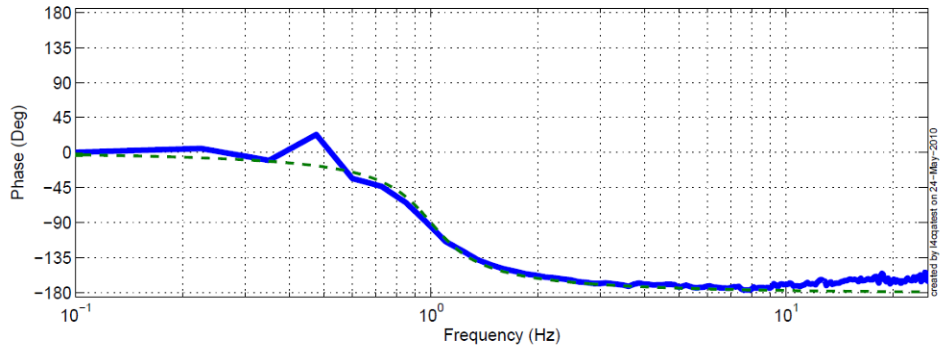
- ***Step 2.2 – Vertical L4Cs***

Huddle testing









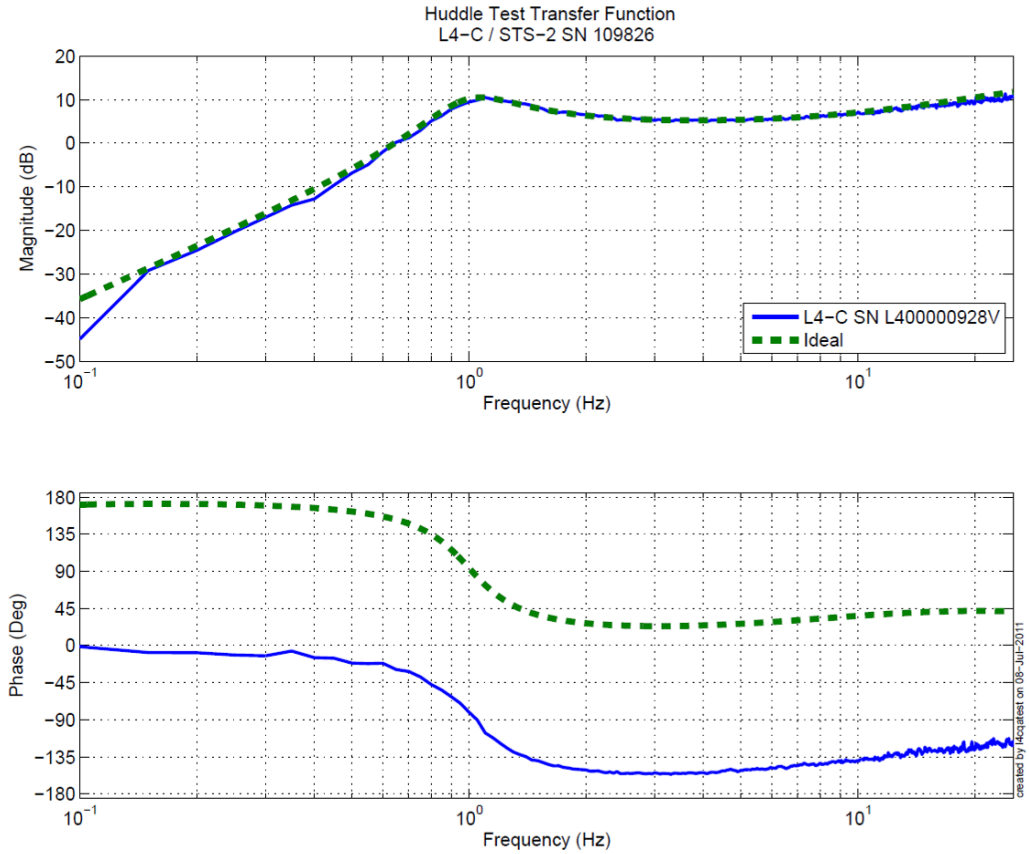


Figure - Huddle testing of Vertical L4-Cs 808, 943, and 928 after aLIGO modifications

Issues/difficulties/comments regarding this test:
One can notice that in half of the L4-C huddle tests, the instrument appears out of phase compared to the model. This was not taken into account in order to approve the instruments for use and was indeed due to a change in the model which should not have been done. (Similarly than with the GS-13s, giving the wrong orientation to the instruments while testing would generate this result)

Acceptance Criteria

- All instruments match their expected response.

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

- ***Step 3: Inventory (E1000052)***

Data shown in red indicate changes made side-chamber.

DCC/Vendor number	Part name	Configuration	S/N	S/N	S/N
D071001	Stage 0 base		5		
D071051	Stage 1 base		6		
D071050	Optical table		13		
D071002	Spring Post		41	40	35
D071100	Spring		36	31	32
D071102	Flexure		8	5	36
ADE	Position sensor	Horizontal	12064	12076	12024
		Vertical	12073	12082	11996
D047812	GS-13 pod	Horizontal	26	35	92
		Vertical	80	64	15
D047823	L4C pod	Horizontal	*100**	*82**	88
		Vertical	128	83	86
D0902749	Actuator	Horizontal	L066	L158	L140
		Vertical	L079	L149	L159

**The S/N with '*' haven't yet been installed but are the ones supposed to be once the current hardware is available.*

Acceptance Criteria

- Inventory is complete

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

- ***Step 4: Check level of Stage 1 Optical Table***

Due to past experience showing we had to adjust the shims both side chamber and in chamber we decided not to run this test.

Acceptance Criteria

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

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

- ***Step 5: Shim thickness***

Issues/difficulties/comments regarding this test: We adjusted shims under locker D (from 120 mils to 124 mils) in order to unlock the table.

Lockers	Shim thickness (mil)
A	122
B	122
C	122
D	124

Table – Shims Thickness

Acceptance Criteria

- Inventory is complete

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

- ***Step 6: Blade spring profile***

Because we know we'll likely have to adjust the shims in chamber, we did not take this measurement.

Acceptance Criteria:

- Blades must be flat within 0.015" inches.

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

- ***Step 7 : Gap checks on actuators-after installation on Stage 1***

Gaps were inspected on all vertical actuators and adjusted to be within requirements. No records were taken. Horizontal actuators will be inspected/adjusted in chambers.

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 8: Mass budget***

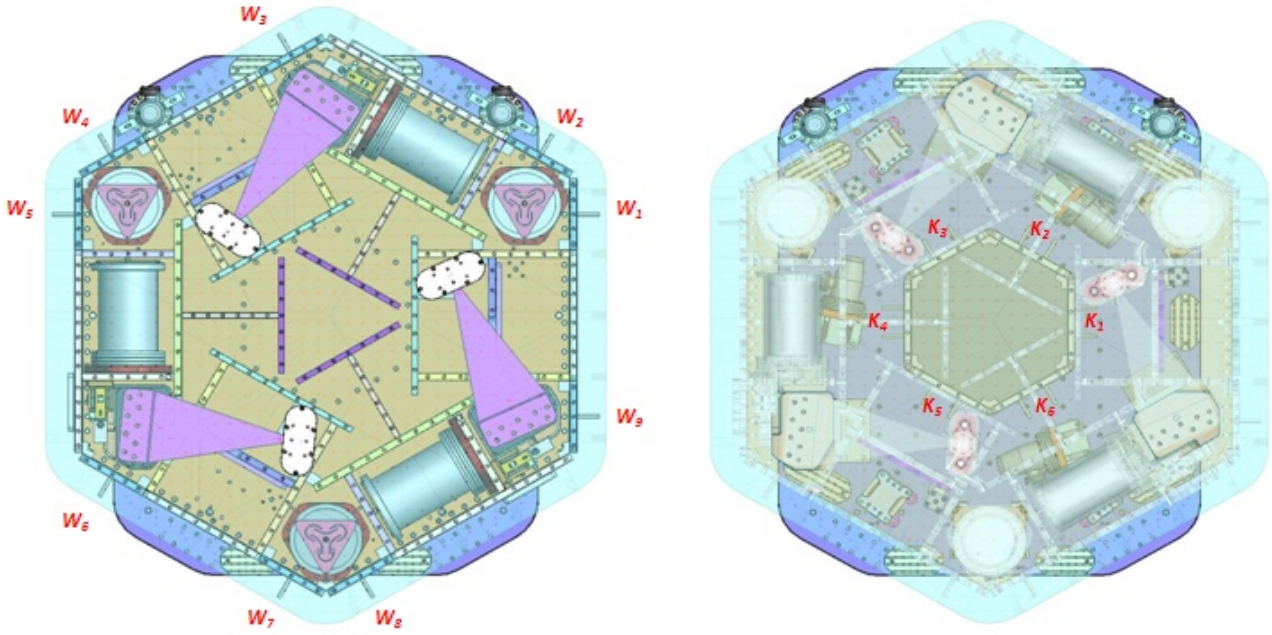


Figure – Keel Masses and Wall masses location

	00	01	02	03	04	05	06		
	0.6	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
w9		2		1	1	2	0	45.8	20.77
w1		1		1	1	0	1	40.7	18.46
w2	1				2	2	0	47.6	21.59
w3					0	1	1	42.8	19.41
w4					1	2	0	39.1	17.74
w5					2	2	0	47	21.32
w6				1	1	2	0	43.6	19.78
w7			1	1	1	2	0	45.8	20.77
w8		1			2	0	1	44.1	20.00
Side Masses Total	1	4	1	4	11	13	3	396.5	179.85

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					1		1	35.1	15.92
k2	1	1	1				1	31.1	14.11
k3					1		1	35.1	15.92
k4	1	1	1				1	31.1	14.11
k5					1		1	35.1	15.92
k6	1	1	1				1	31.1	14.11
	3	3	3	0	3	0	6	198.6	90.08

Table – Keel masses distribution

	D972213	D972215	D0901075				
			2.5 kg	5 kg	10 kg		
	610	230	5.5	11	22	lbs	kgs
A	1					610	276.69
B						0	0.00
C						0	0.00
D						0	0.00
E-1					1	22	9.98
E-2					1	22	9.98
E-3					1	22	9.98
Top Masses	1	0	0	0	3	676	306.63

Table - Optical Table Masses distribution

	Side	Keel	Top	Total
Weigh (kg)	179.85	90.08	306.63	576.56

Table - Masses distribution (computed using T1100261)

Acceptance Criteria

The Mass budget must be

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

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

- ***Step 9: Lockers adjustment***

We used dial indicators for initial balancing, but fine balancing and locker adjustment was done using the CPSs. (See Step 12).

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

- ***Step 10 - Electronics Inventory***

Hardware	LIGO reference	S/N
Binary Input*	D1001726	S1101288
Binary Output*	D1001728	S1101323
Coil driver	D0902744	S1103324
		S1103325
Anti Image filter	D1100202	S1200319
Anti aliasing filter	D1000269	S1107529
		S1200313
Interface chassis	D1002432	S1107866
		S1107867
		S1107868

Table - Inventory electronics

Issues/difficulties/comments regarding this test: Binary Input and Output interfaces are shared between HAM 4 and HAM 5.

Acceptance Criteria

- Inventory is complete

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

- ***Step 11 – Cables inventory – E1100822***

The location of all cables must be reported in the spreadsheet E1100822.

Cable Connects		Cable S/N		
Part Name	**Configuration**	**Corner 1**	**Corner 2**	**Corner 3**
GS13	Horizontal	S1104655-S1104610	S1104688-S1004591	S1104665-S1104698
GS13	Vertical			
L4C	Horizontal	S1104654-S1104691	S1104646-S1104604	S1104666-S1104605
L4C	Vertical			
Actuator	Horizontal	S1104485	S1104497	S1106681
	Vertical	S1104753	S1104721	S1104741

Table – Cables inventory

Acceptance Criteria

- Cable inventory completed
- E110082 spreadsheet updated

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

- ***Step 12 - Set up sensors gap***

	No mass	
Table locked	ADE boxes on	
Sensors	Offset (Mean)	Std deviation
H1	73.01	5.6836
H2	-134.73	5.5749
H3	-187.21	6.2337
V1	220.81	5.268
V2	128.05	8.2786
V3	102.48	6.3033

Table – Capacitive position sensor readout after gap set-up

Issues/difficulties/comments regarding this test: HAM-ISI – LLO HAM 4 uses synchronized boxes, with power boards installed on their back.

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: X** **Failed: __**

- ***Step 13 - Measure the Sensor gap***

This test was not done any more due to risk of damage to sensor targets.

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

- ***Step 14 - Check Sensor gaps after the platform release***

	Table locked		Table unlocked	
Sensors	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Difference**
H1	73.01	5.6836	-794.75	-867.76
H2	-134.73	5.5749	1154.2	1288.93
H3	-187.21	6.2337	-1554.7	-1367.49
V1	220.81	5.268	-715.18	-935.99
V2	128.05	8.2786	983.09	855.04
`V3	102.48	6.3033	123.97	21.49

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")
- 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: X** **Failed: ___**

- ***Step 15– Performance of the limiter***
- ***Step 15.1 - Test Nº1 - Push "in the general coordinates"***

	CPS read out		Calculated after calibration	
Sensors	**UP (Counts)**	**Down (Counts)**	**UP (mil)**	**Down (mil)**
V1	20036	-20430	23.8	-24.3
V2	21219	-20043	25.2	-23.8
V3	19490	-19796	23.2	-23.5
	CPS read out		**Calculated after calibration**	
Sensors	**CW(-RZ)**	**CCW (+RZ)**	**CW (mil)**	**CCW (mil)**
H1	20224	-21288	24.0	-25.3
H2	20954	-19715	24.9	-23.4
H3	23173	-23236	27.6	-27.6

Table - Optic table range of motion

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 15.1

- Absolutes value of all estimated motions must be higher than 16000counts (~0.020")

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

- ***Step 16 - Position Sensors unlocked/locked Amplitude Spectral Densities***

Data files in SVN at:
/seismic/HAM-ISI/L1/HAM4/Data/Spectra/Undamped/
- LLO_ISI_HAM4_ASD_m_CPS_T240_L4C_GS13_Locked_vs_Unlocked_2012_05_22.pdf

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Plot_ASD_Unlocked_Locked_HAM_ISI.m
- Plot_ASD_Unlocked_Locked_Group_HAM_ISI.m

Figures in SVN at:
seismic/HAM-ISI/L1/HAM4/Data/Figures/Spectra/Undamped/
- LLO_ISI_HAM4_ASD_m_CPS_Requirements_Locked_vs_Unlocked_2012_05_22.pdf
- LLO_ISI_HAM4_ASD_m_GS13_Requirements_Locked_vs_Unlocked_2012_05_22.pdf

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

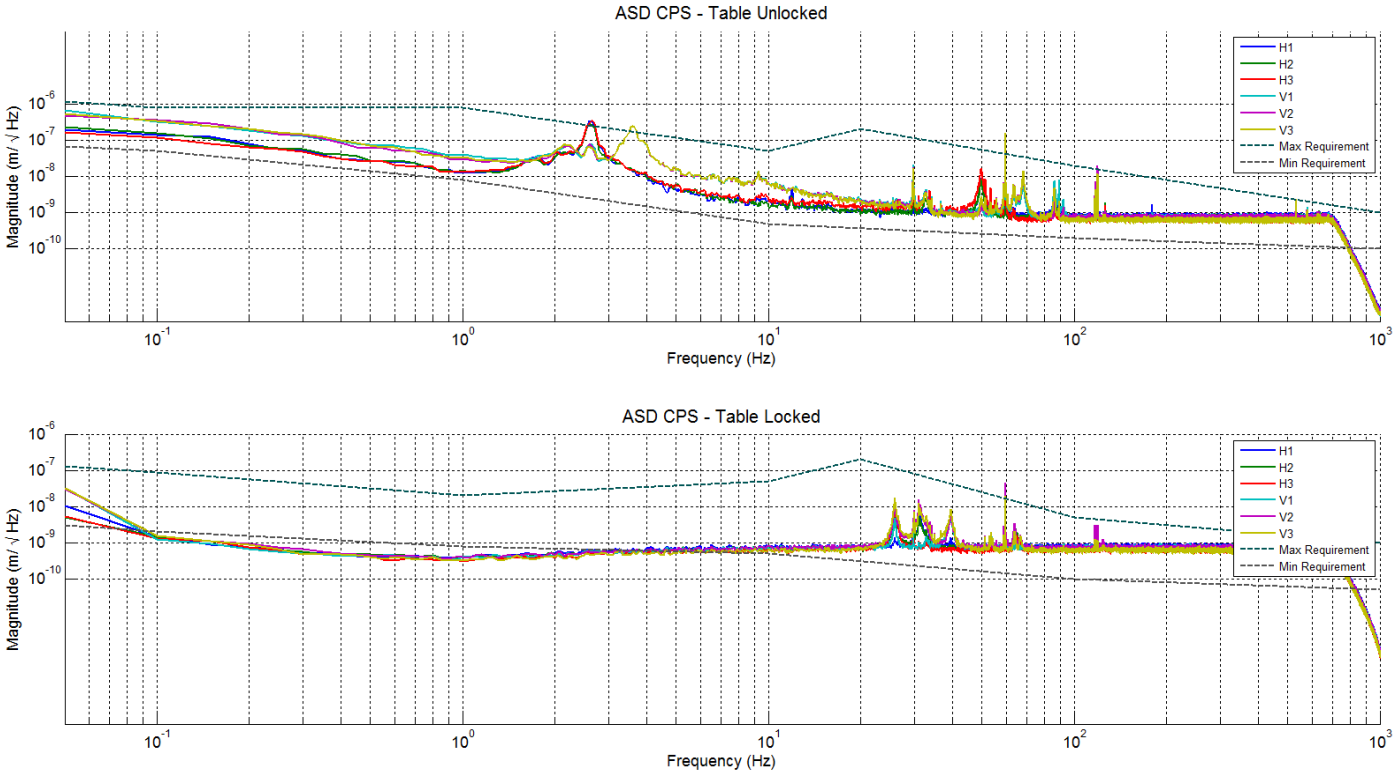


Figure - Calibrated CPS power spectrum

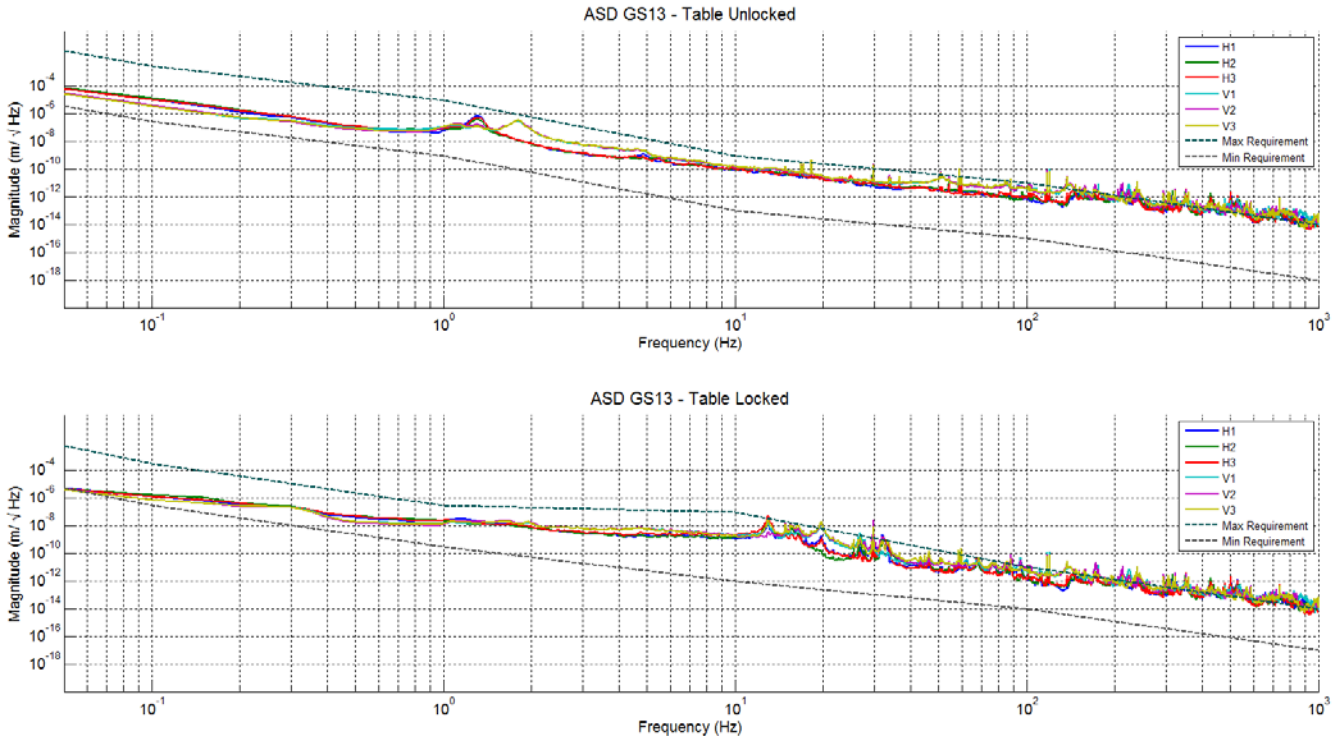


Figure – Power spectrum Calibrated GS13s

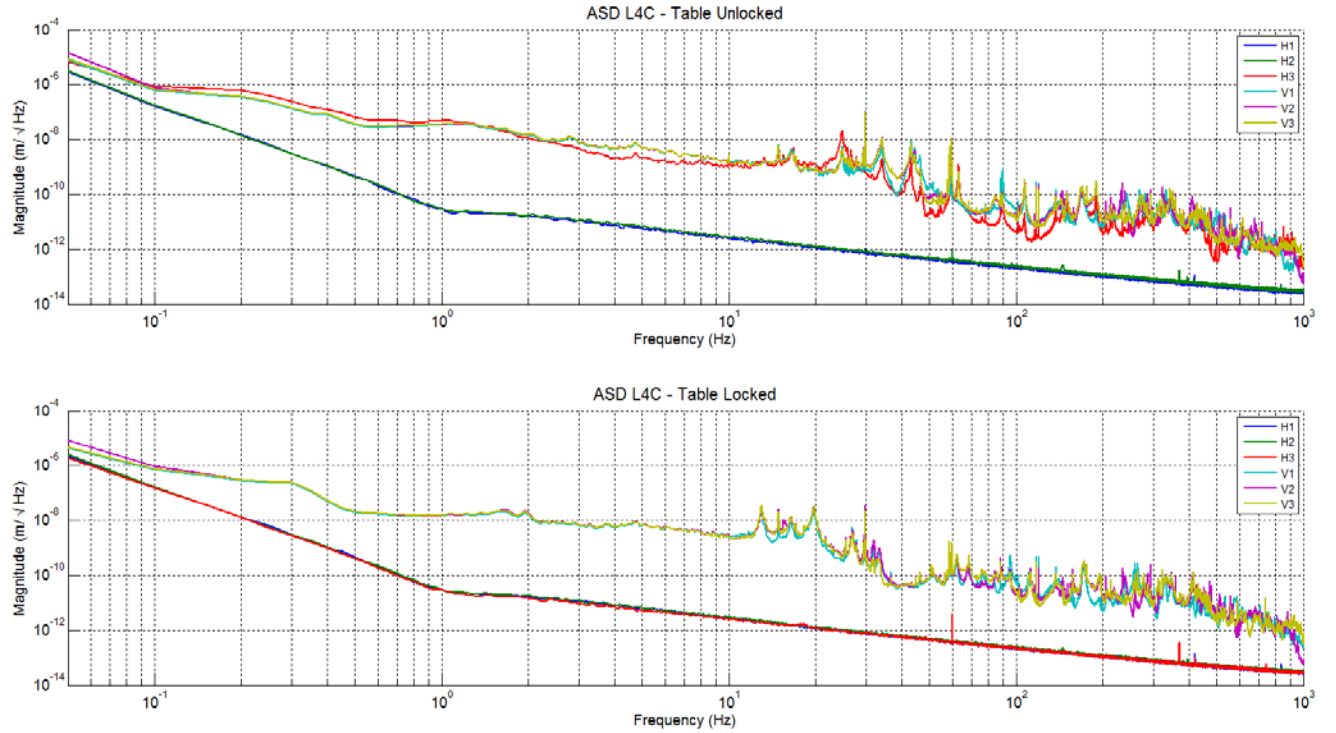


Figure – Power spectrum Calibrated L4-Cs

Acceptance criteria:

- No cross talk (peaks at low frequencies + harmonics on measurements)
- Magnitudes of power spectra must be between requirement curves such as in the following figures (dashed lines)

Issues/difficulties/comments regarding this test:
This was the first unit equipped with Feedforward L4Cs, therefore no requirement curves were available. However, we can notice that all installed sensors behave in a similar fashion, implying good functioning.
Note that H1 and H2 were not installed at the unlocked time, whereas H1, H2 and H3 were not at the locked time. Those curves therefore only display ADC noise.

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

- ***Step 17 - GS13 ASD -tabled tilted***

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

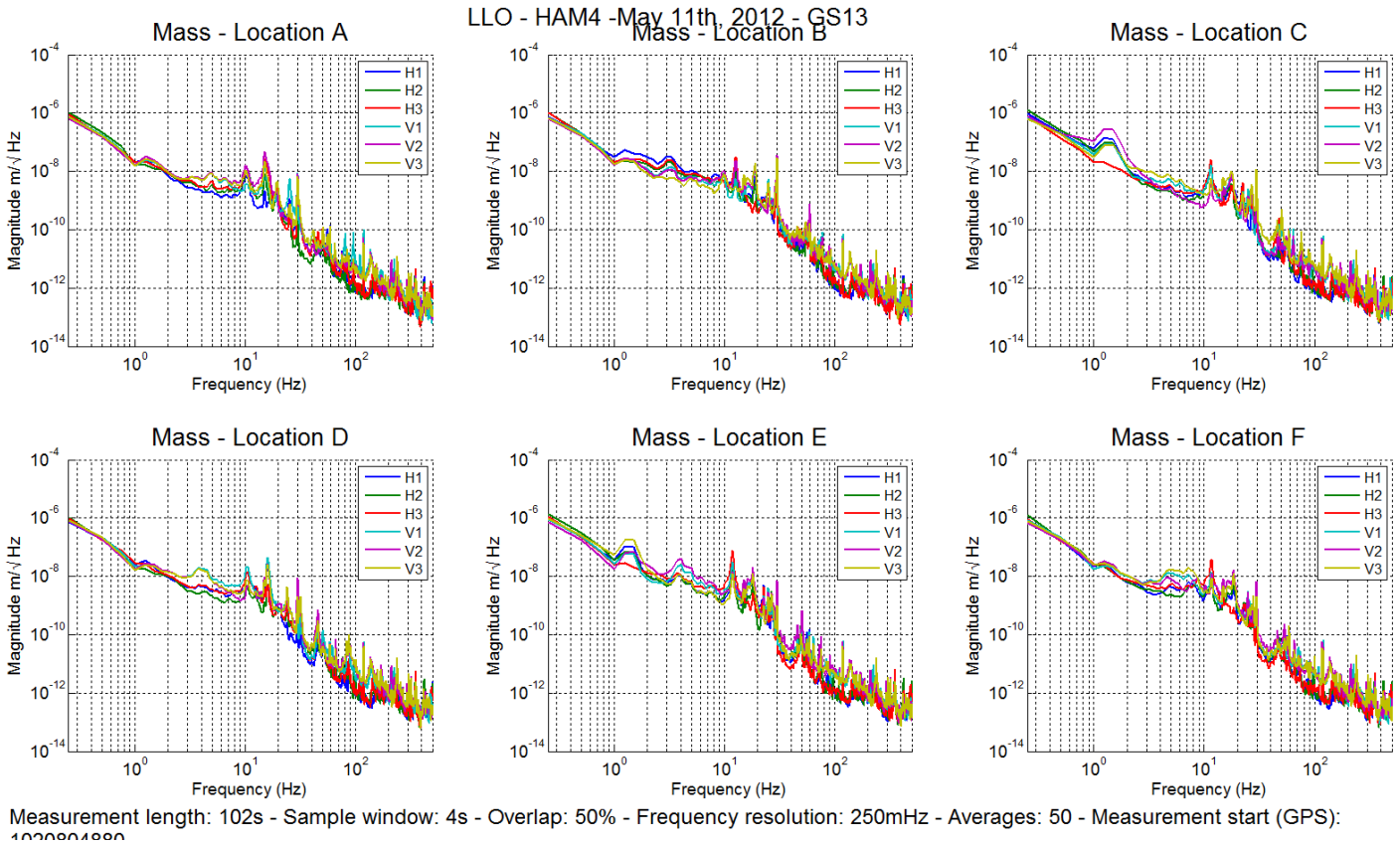


Figure – ASD Calibrated GS13 with mass at corner

Data files in SVN at:
/seismic/HAM-ISI/L1/HAM4/Data/Spectra/Undamped/
- LLO_HAM_ISI_Unit_3_Calibrated_PSD_GS13_Table_Tilted_2012-05-14.mat

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Plot_ASD_Tilted_Stage_HAM_ISI.m

Figures in SVN at:
seismic/HAM-ISI/L1/HAM4/Data/Figures/Spectra/Undamped/
- LLO_ISI_HAM4_ASD_CT_GS13_Tilted_2012_05_14.pdf

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

Issues/difficulties/comments regarding this test:

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

- ***Step 18- GS13 pressure readout***

As of 05/23/12, readout was as follow:

	Corner 1	Corner 2	Corner 3
L4-C Direct Pressure	99	99	100
L4-C Diff Pressure	-9	-9	0
GS-13 Direct Pressure	75	97	77
GS-13 Diff Pressure	0	1	0

Acceptance criteria:
- The pressure on direct channels must be 102KPa +/-8 KPa
- The pressure on differential channels must be 0KPa +/-8 KPa

Issues/difficulties/comments regarding this test:
The channels in yellow do not pass because seismometers are not connected yet (L4-C H1 and H2).
The channels in orange do not pass because of a gain difference in the GS-13 channels of the HAM-ISI interfaces. Those out of vacuum electronics will be corrected.

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

- ***Step 19 - Actuators Sign and range of motion (Local drive)***

	Negative drive	Initial offset	Positive drive
H1 readout (count)	-24065.2	-1275	22978.19
H2 readout (count)	-23595.7	-776	23594.1
H3 readout (count)	-24198.4	423	25295.62
V1 readout (count)	-19326.6	386	19445.11
V2 readout (count)	-24525.8	3010	24869.71
V3 readout (count)	-22336.5	3229	19933.63

Table - Range of motion - Local drive

Data files in SVN at:
/seismic/HAM-ISI/L1/HAM4/Data/Static_Tests/
- LLO_ISI_HAM4_Range_Of_Motion_20120511.mat

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Range_Motion_HAM_ISI.m

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 20 - Static Testing (Tests in the local basis)***

	H1	H2	H3	V1	V2	V3
H1	1835.687	1138.897	1151.372	-2.3742	-0.4244	2.9375
H2	1135.696	1820.86	1143.706	4.4074	13.6528	0.54178
H3	1160.105	1153.613	1865.289	7.084	-2.5676	3.70468
V1	169.3728	162.4318	-336.416	1295.793	-17.8158	-548.171
V2	-327.863	167.5004	164.1132	-550.289	1301.876	-36.2337
V3	166.4284	-339.946	176.1794	-44.563	-547.276	1303.788

Table - Main and cross coupling

Data files in SVN at:
/seismic/HAM-ISI/L1/HAM4/Data/Static_Tests/

- LLO_ISI_HAM4_Offset_Local_Drive_20120511.mat

Scripts files for taking data in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/

- Static_Test_Local_Basis_HAM_ISI.m

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 21- Linearity test***

	Slope	Offset	Average slope	Variation from average(%)
H1	1.835332	-590.165	1.837775	-0.13291
H2	1.82094	850.3225		-0.91606
H3	1.857053	-1682.42		1.048971
V1	1.298961	-1625.3	1.293858	0.394371
V2	1.288567	-1134.8		-0.40895
V3	1.294047	-405.793		0.014584

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

Scripts files for taking data in SVN at:
/seismic/HAM-ISI/Common/ Common/Testing_Functions_HAM_ISI

- Linearity_Test_Awgstream_HAM_ISI.m

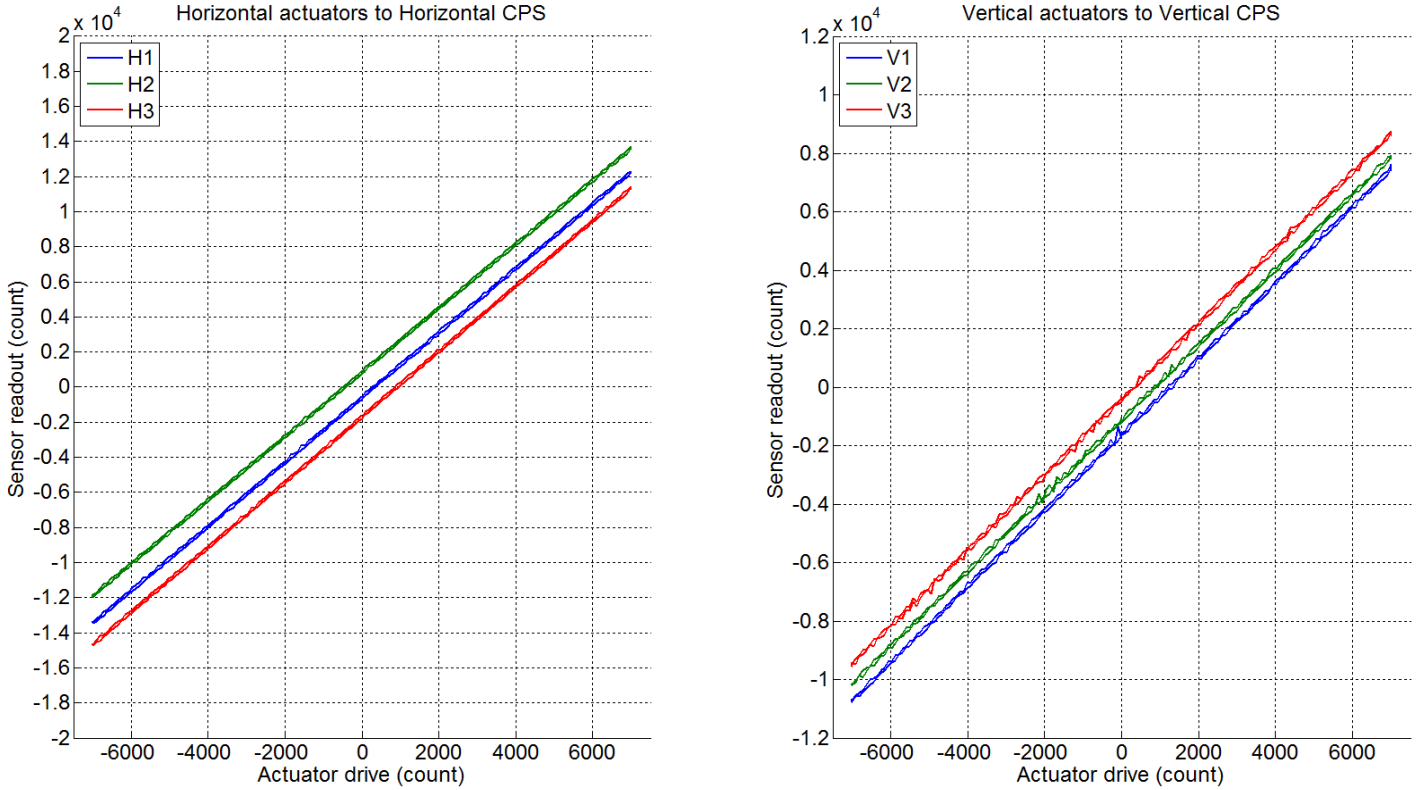


Figure - Horizontal and vertical actuators x HAM-ISI x sensors

Data files in SVN at:
seismic/HAM-ISI/L1/HAM4/Data/Linearity_Test/

- LLO_ISI_HAM4_Linearity_test_20120511.mat

Figures in SVN at:
seismic/HAM-ISI/L1/HAM4/Data/Figures/Linearity_Test/

- LLO_ISI_HAM4_Linearity_test_20120511.pdf

Issues/difficulties/comments regarding this test:

We can see that H3 seems to have an offset slightly higher than expected (i.e. 1% to average). But it was deemed close enough to be acceptable here.

Acceptance criteria:

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

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

- ***Step 22 Cartesian Basis Static Testing***

1000 counts Drive	H1	H2	H3	V1	V2	V3
X Drive	214.5826	219.7652	-471.823	3.311	4.948	-1.23734
Y Drive	-410.522	385.5736	-11.8988	3.139	15.9778	19.69964
Z Drive	-5.82204	-4.7258	0.5554	245.8052	242.9124	249.5203
Rx Drive	-408.671	406.6346	-3.9936	-426.447	1499.0258	-1054.34
Ry Drive	-247.154	-235.816	472.6269	-1491.01	386.9316	1124.647
Rz Drive	-1785.31	-1786.01	-1787.54	-2.5272	9.7908	8.22994

Table - Tests in the local coordinate basis

1000 counts Drive	X	Y	Z	RX	RY	RZ
X Drive	458.873	8.0697	8.54174	10.8978	-4.0878	13.24648
Y Drive	-1.1212	458.48534	7.62832	2.3792	3.4236	13.12644
Z Drive	-1.5728	-0.63654	247.272538	-21.3866	-3.972	-1.8403
Rx Drive	1.5706	0.87544	8.75582	2275.0006	-4.645	2.4608
Ry Drive	-2.4496	3.4339	11.99876	13.6508	2302.4724	9.13544
Rz Drive	6.5078	1.12168	14.01746	-3.3526	8.903	2260.68424

Table - Tests in the general coordinate basis

Acceptance criteria:

- For a positive drive in the Cartesian basis Local sensor readout must have the same sign that in the following table:

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	-	-	-				+

Table – Reference table

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

Issues/difficulties/comments regarding this test:
The difference in response in the different directions is relatively surprising, but at worse, this would only indicate a matrix issue, which does not have incidence in deciding to install the HAM-ISI.

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

- ***Step 23- Frequency response***

- ***Step 23.1 - Local to local measurements***

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

Data files in SVN at:
seismic/HAM-ISI/L1/HAM4/Data/Transfer_Functions/Measurements/Undamped/
- LLO_ISI_HAM4_Data_TF_L2L_ 50mHz_500mHz_20120521-220711.mat
- LLO_ISI_HAM4_Data_TF_L2L_ 500mHz_5Hz_20120521-155738.mat
- LLO_ISI_HAM4_Data_TF_L2L_ 5Hz_200Hz_20120521-142405.mat
- LLO_ISI_HAM4_Data_TF_L2L_200Hz_800Hz_20120521-105352.mat

Data collection script files:
seismic/HAM-ISI/L1/HAM4/Scripts/Data_Collection/
- Run_Exc_Batch_L1ISIHAM4.m

Scripts files for processing and plotting in SVN at:
seismic/HAM-ISI/L1/HAM4/Scripts/Control_Scripts/release/
- Step_1_TF_Loc_2_Loc_L1_ISI_HAM4.m

(note that here release was soft linked to Version_1)

Figures in SVN at:
/seismic/HAM-ISI/L1/HAM4/Data/Figures/Transfer_Functions/Measurements/Undamped/
- LLO_ISI_HAM4_TF_L2L_Raw_from_ACT_to_CPS_2012_05_21.fig
- LLO_ISI_HAM4_TF_L2L_Raw_from_ACT_to_GS13_2012_05_121.fig

Storage of measured transfer functions in the SVN at:
seismic/ HAM-ISI/L1/HAM4/Data/Transfer_Functions/Simulations/Undamped
- L1_ISI_HAM4_TF_L2L_Raw_2012_05_21.mat
-

The local to local transfer functions are presented below.

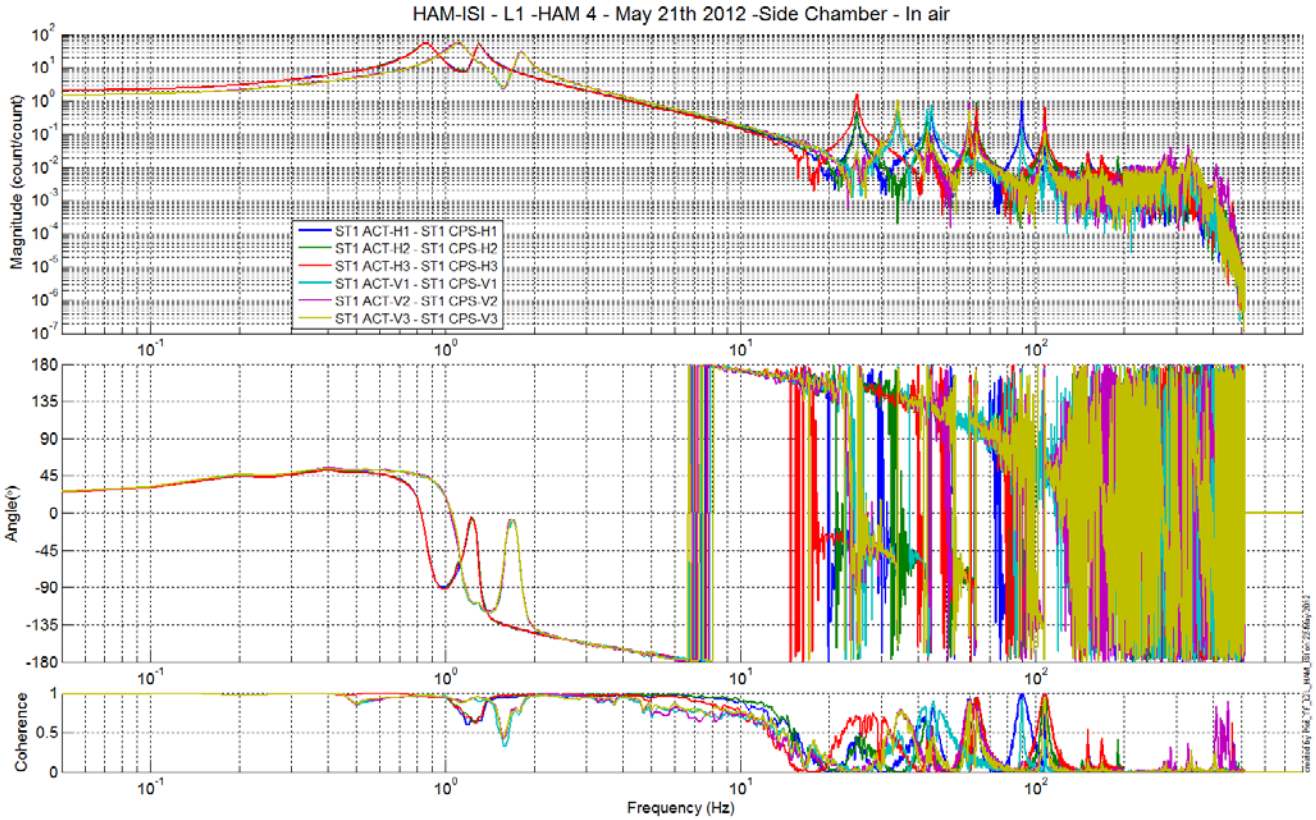


Figure - Local to Local Measurements –Capacitive Position Sensors

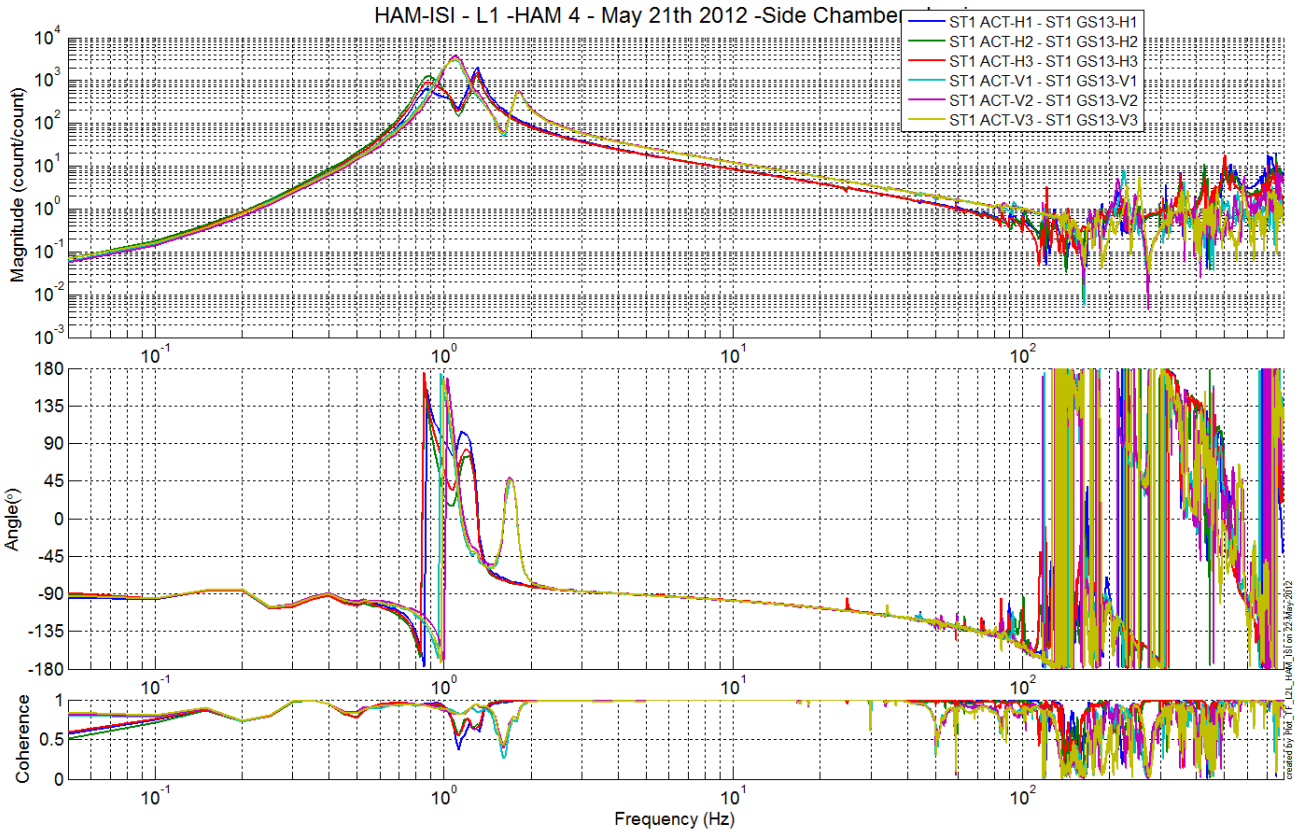


Figure - Local to Local Measurements – Inertial sensors

Issues/difficulties/comments regarding this test:
We can see that horizontal sensors in corner 1 and 3 seem to see a slightly different behavior around 1 Hz. We tried to assess whether this could be due to the GS-13 characteristics themselves by extracting the sensor response from the transfer function and comparing this to the huddle test results.

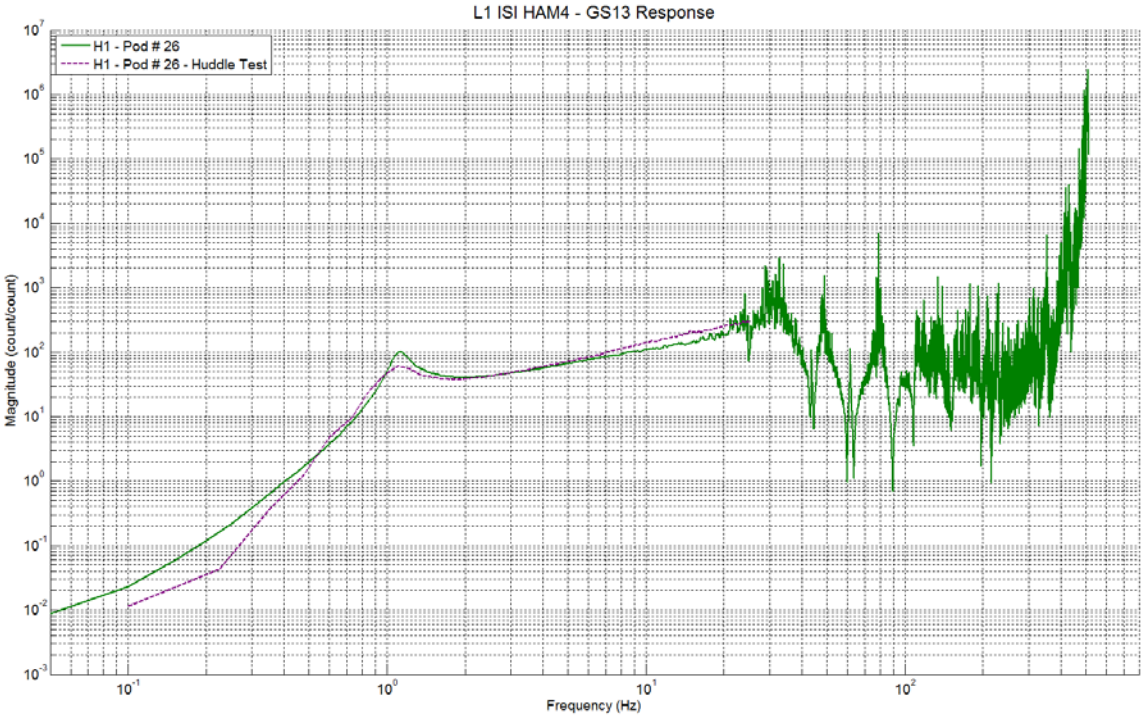
Data collection script files:
seismic/HAM-ISI/L1/HAM4/Scripts/Data_Collection/

- L1_HAM4_GS13_Resp_Extraction_Fitting.m

Figures in SVN at:
/seismic/HAM-ISI/L1/HAM4/Data/Figures /Instrument_Responses/GS13/

- L1_ISI_HAM4_GS13_H1_Pod_26_Extracted_Response_VS_Huddle.fig
- L1_ISI_HAM4_GS13_H1_Pod_35_Extracted_Response_VS_Huddle.fig
- L1_ISI_HAM4_GS13_H1_Pod_92_Extracted_Response_VS_Huddle.fig
- L1_ISI_HAM4_GS13_H1_Pod_80_Extracted_Response_VS_Huddle.fig
- L1_ISI_HAM4_GS13_H1_Pod_64_Extracted_Response_VS_Huddle.fig
- L1_ISI_HAM4_GS13_H1_Pod_15_Extracted_Response_VS_Huddle.fig

Here are the plots for the 3 horizontal sensors:



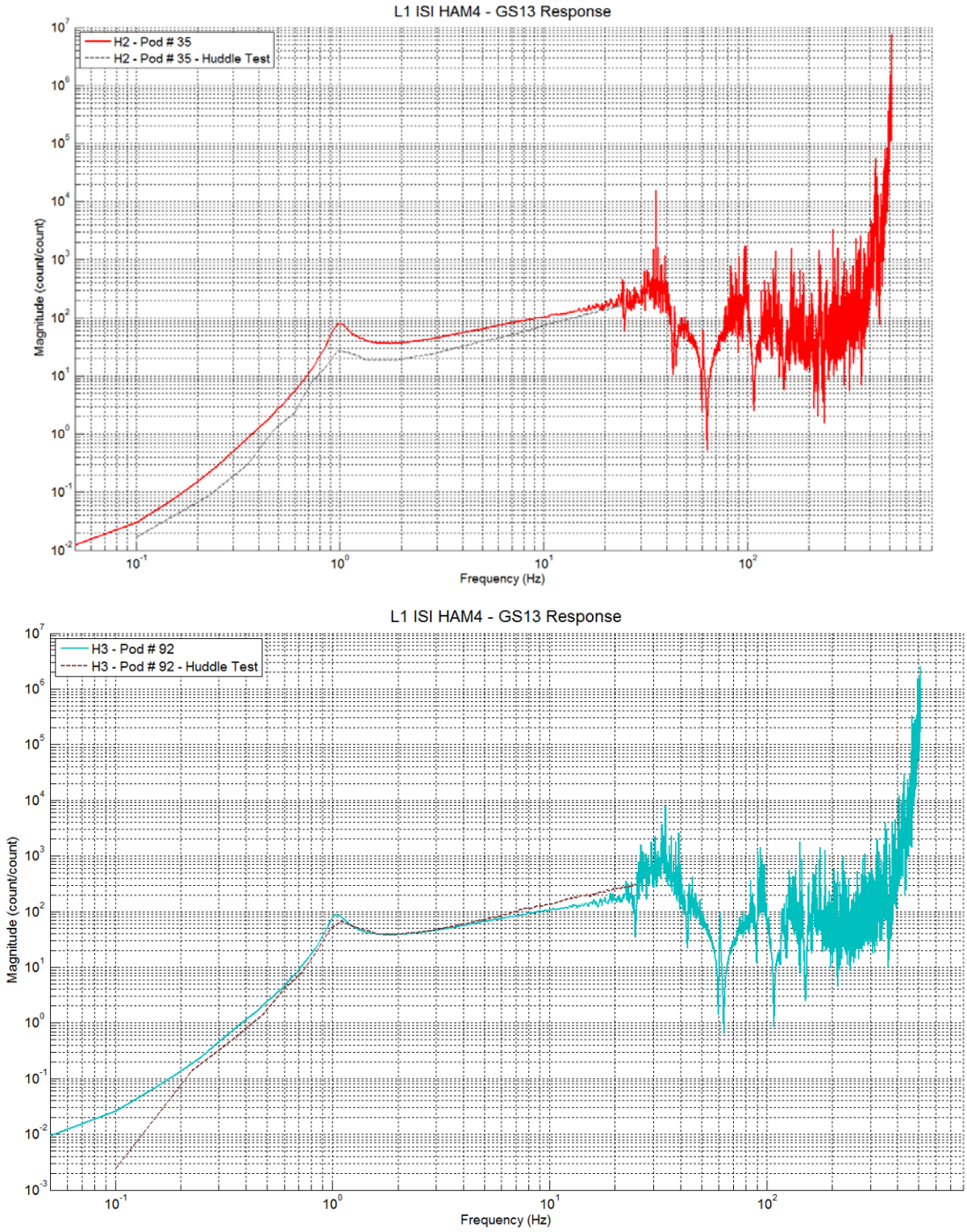


Figure – Comparison between the responses of the horizontal GS-13s installed on HAM-ISI 4 and their respective huddle test results.

From those last three plots, we can notice that H1 in partical appears to have a slightly higher resonant frequency than the other horizontal sensors, which may partly explain the slight difference between the horizontal corners. (Indeed in corners 2 and 3, the resonant frequencies of the ISI may be superposed to the sensor resonant frequency).

Conclusion of Side Chamber testing

Only a few minor issues were found during testing of this ISI:

- Slightly different actuator slope on H3 (in comparison to the other horizontal actuators)
- Slightly different response of the H1 GS-13 (in comparison to H1 and H2) between 0.8 and 1.1 Hz. This appears to be explained by the different sensors responses.
-

A number of mechanical tests (and adjustments) were waived at the time of side-chamber testing, leaving this for in-chamber initial testing:

- Level of the optical table
- Spring flatness measurements
- Horizontal actuator gaps

II. INITIAL CHAMBER TESTING

This HAM-ISI was installed inside HAM 4 on May 29th 2012. Because of purge air issues and difficulties with in-vacuum cables, it was only finally connected on June 14th 2012. Testing was conducted in the following week.

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

Issues/difficulties/comments regarding this test:
Initially this test was failed, but we adjusted the shim thickness to pass this test (see following step for new locker shims).
The table here does not appear to be really tilted. Most of the difference can be included within the .005" flatness of the table.

Acceptance Criteria

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

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

- ***Step 2: Ground loops***

We checked that there was no electrical connection between the coil and the chamber, .

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

- ***Step 3: Blade spring profile***

Because we adjusted the shims, we retook this measurement:

Blade #	Base (")	Tip(")	Flatness (mils)
1	0.5121	0.4943	17.8
2	0.5117	0.4959	15.8
3	0.4962	0.4926	3.6

Table 1 - Blade profile

Acceptance Criteria:

- Blades must be flat within 0.015" inches.

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

- ***Step 4: Mass budget***

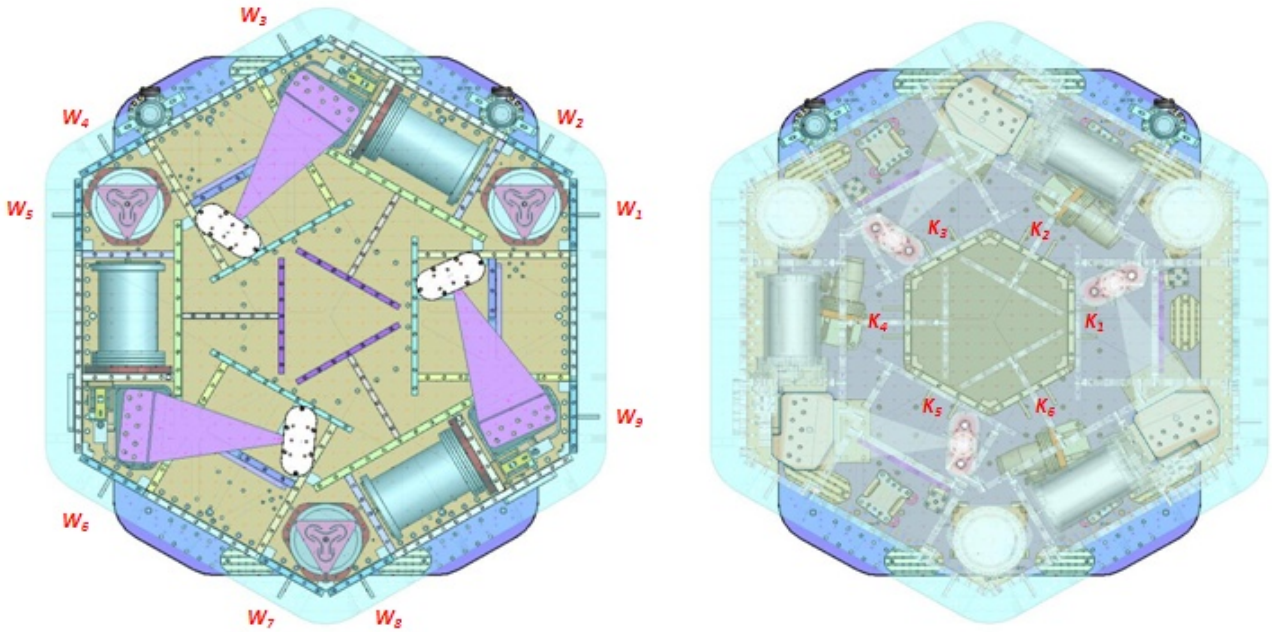


Figure – Keel Masses and Wall masses location

Figure - Optical table masses distribution

06/20/12	00	01	02	03	04	05	06		
	0.6	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
w9		0	1	1	1	2	0	45.8	20.77
w1		1		1	1	0	1	40.7	18.46
w2			1		2	2	0	49.2	22.32
w3					0	1	1	42.8	19.41
w4					1	2	0	39.1	17.74
w5					2	2	0	47	21.32
w6				1	1	2	0	43.6	19.78
w7		1		1	1	2	0	44.7	20.28
w8		1			2	0	1	44.1	20.00
Side Masses Total	0	3	2	4	11	13	3	397	180.08

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					1		1	35.1	15.92
k2	1	1	1				1	31.1	14.11
k3					1		1	35.1	15.92
k4	1	1	1				1	31.1	14.11

k5					1		1	35.1	15.92
k6	1	1	1				1	31.1	14.11
	3	3	3	0	3	0	6	198.6	90.08

Table – Keel masses distribution

	D972213	D972215	D0901075				
			2.5 kg	5 kg	10 kg		
	610	230	5.5	11	22	lbs	kgs
A	1					610	276.69
B						0	0.00
C						0	0.00
D						0	0.00
E-1					1	22	9.98
E-2					1	22	9.98
E-3					1	22	9.98
Top Masses	1	0	0	0	3	676	306.63

Table - Optical Table Masses distribution

	Side	Keel	Top	Total
Weigh (kg)	180.08	90.08	306.63	576.79

Table - Masses distribution (computed using T1100261)

Acceptance Criteria

The Mass budget must be

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

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

- ***Step 5: Lockers adjustment***

- Not recorded but within.

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

- ***Step 6 – Cables inventory – E1100822***

We made a mistake while connecting cables from corner 1 and exchanged L4C with GS-13. Due to the hard difficult location of the corner 1 feedthru, we were unable to swap those cables at the feedthru and ending up swapping those at the connection between the pig tail and the extension.

Cable Connects		Cable S/N		
Part Name	**Configuration**	**Corner 1**	**Corner 2**	**Corner 3**
GS13	Horizontal	S1104654-S1104610	S1104688-S1004591	S1104665-S1104698
GS13	Vertical			
L4C	Horizontal	S1104655-S1104691	S1104646-S1104604	S1104666-S1104605
L4C	Vertical			
Actuator	Horizontal	S1104485	S1104497	S1106681
	Vertical	S1104753	S1104721	S1104741

Table – Cables inventory

Acceptance Criteria

- Cable inventory completed
- E110082 spreadsheet updated

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

- ***Step 7 - Check Sensor gaps after the platform release***

	Table locked		Table unlocked	
Sensors	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Difference**
H1	214.18	4.94	884.78	-670.6
H2	-584.07	3.89	1358	-1942.07
H3	917.16	3.85	-912.57	1829.73
V1	415.81	4.23	-560.69	976.5
V2	976.06	4.81	1166.9	-190.84
`V3	-589.72	4.18	-2196.3	1606.58

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")
- 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")

Issues/difficulties/comments regarding this test:
We are barely passing this test but since this is not the final balancing, this is good enough.

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

- ***Step 8 - Position Sensors unlocked/locked Amplitude Spectral Densities***

Data files in SVN at:
/seismic/HAM-ISI/L1/HAM4/Data/Spectra/Undamped/
- LLO_ISI_HAM4_ASD_m_CPS_T240_L4C_GS13_Locked_vs_Unlocked_2012_06_15.mat

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Plot_ASD_Unlocked_Locked_HAM_ISI.m
- Plot_ASD_Unlocked_Locked_Group_HAM_ISI.m

Figures in SVN at:
seismic/HAM-ISI/L1/HAM4/Data/Figures/Spectra/Undamped/
- LLO_ISI_HAM4_ASD_m_CPS_Requirements_Locked_vs_Unlocked_2012_06_15.fig
- LLO_ISI_HAM4_ASD_m_GS13_Requirements_Locked_vs_Unlocked_2012_06_15.pdf

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

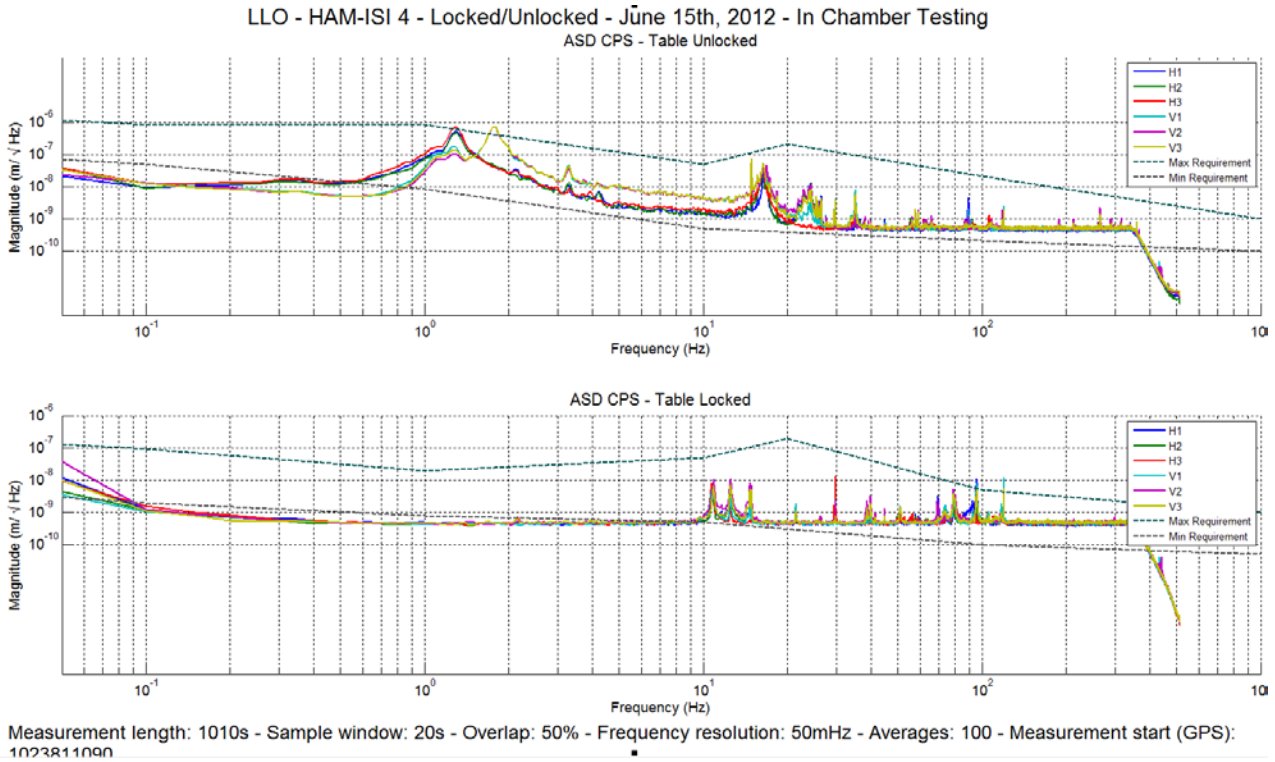


Figure - Calibrated CPS power spectrum

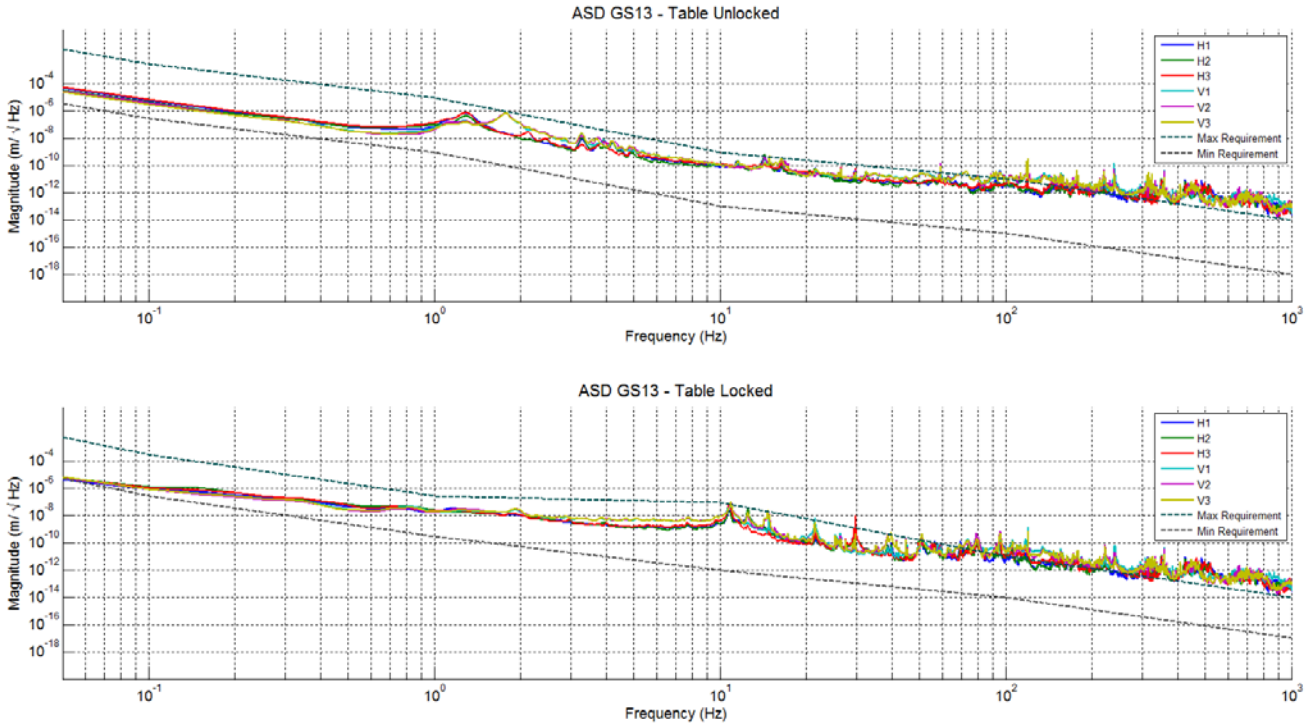


Figure – Power spectrum Calibrated GS13

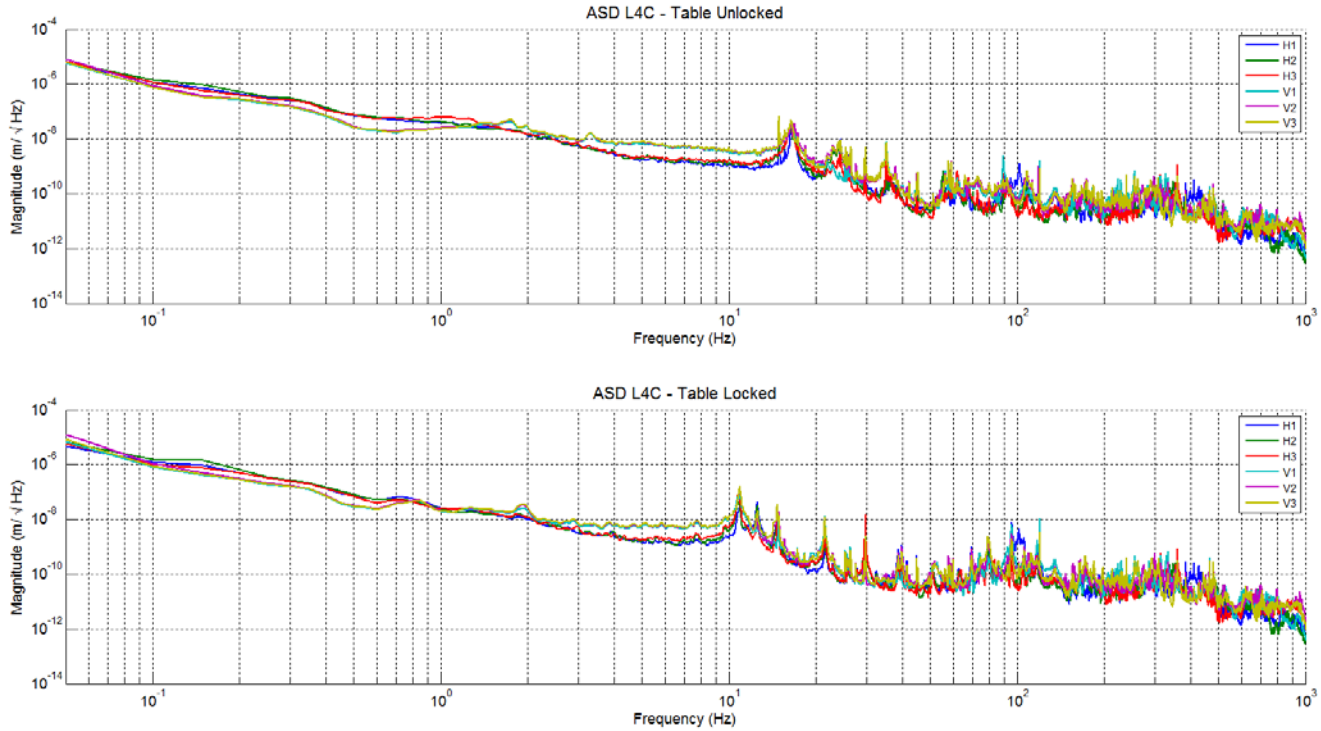


Figure – Power spectrum Calibrated L4C

Acceptance criteria:

- No cross talk (peaks at low frequencies + harmonics on measurements)
- Magnitudes of power spectra must be between requirement curves such as in the following figures (dashed lines)

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

- ***Step 9 - GS13 ASD -table tilted***

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

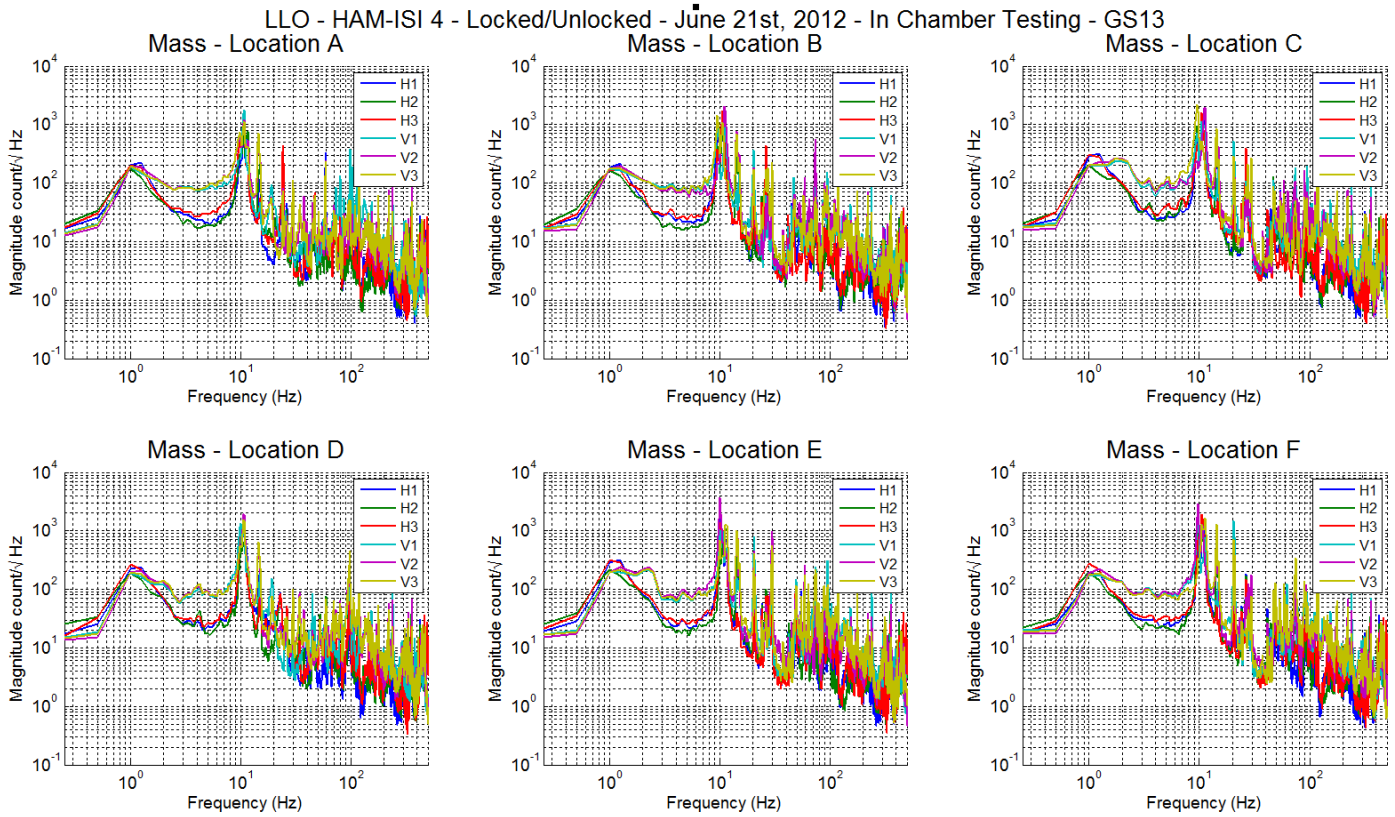


Figure – ASD Calibrated GS13 with mass at corner

Data files in SVN at:
/seismic/HAM-ISI/L1/HAM4/Data/Spectra/Undamped/
- LLO_ISI_HAM4_Calibrated_PSD_GS13_Table_Tilted_2012-06_21.mat

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Plot_ASD_Tilted_Stage_HAM_ISI.m

Figures in SVN at: seismic/HAM-ISI/L1/HAM4/Data/Figures/Spectra/Undamped/
- LLO_ISI_HAM4_ASD_CT_GS13_Tilted_2012_06_21.pdf

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

- ***Step 10- GS13 pressure readout***

As of 09/18/12, readout was as follow:

	Corner 1	Corner 2	Corner 3
L4-C Direct Pressure	98	98	99
L4-C Diff Pressure	-1	-1	0
GS-13 Direct Pressure	75	97	76
GS-13 Diff Pressure	0	1	0

Acceptance criteria:
- The pressure on direct channels must be 102KPa +/-8 KPa
- The pressure on differential channels must be 0KPa +/-8 KPa

Issues/difficulties/comments regarding this test:
The channels in yellow do not pass because seismometers are not connected yet (L4-C H1 and H2).
The channels in orange do not pass because of a gain difference in the GS-13 channels of the HAM-ISI interfaces. Those out of vacuum electronics will be corrected.

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

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

	Negative drive	Positive drive
H1 readout (count)	-24065.2	22978.19
H2 readout (count)	-23595.7	23594.1
H3 readout (count)	-24198.4	25295.62
V1 readout (count)	-19326.6	19445.11
V2 readout (count)	-24525.8	24869.71
V3 readout (count)	-22336.5	19933.63

Table - Range of motion - Local drive

Data files in SVN at:
/seismic/HAM-ISI/L1/HAM4/Data/Static_Tests/
- LLO_ISI_HAM4_Range_Of_Motion_20120615.mat

Scripts files for taking and processing the data, and plotting it in SVN at:
seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/
- Range_Motion_HAM_ISI.m

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 12 - Linearity test***

	Slope	Offset	Average slope	Variation from average(%)
H1	1.918975	890.7247	1.921595	-0.136
H2	1.904529	1367.758		-0.888
H3	1.941281	-894.263		1.024
V1	1.347808	-563.167	1.353798	-0.443
V2	1.345337	1174.127		-0.625
V3	1.36825	-2198.45		1.068

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

Scripts files for taking data in SVN at: seismic/HAM-ISI/Common/Testing_Functions_HAM_ISI/

- Linearity_Test_Awgstream_HAM_ISI.m

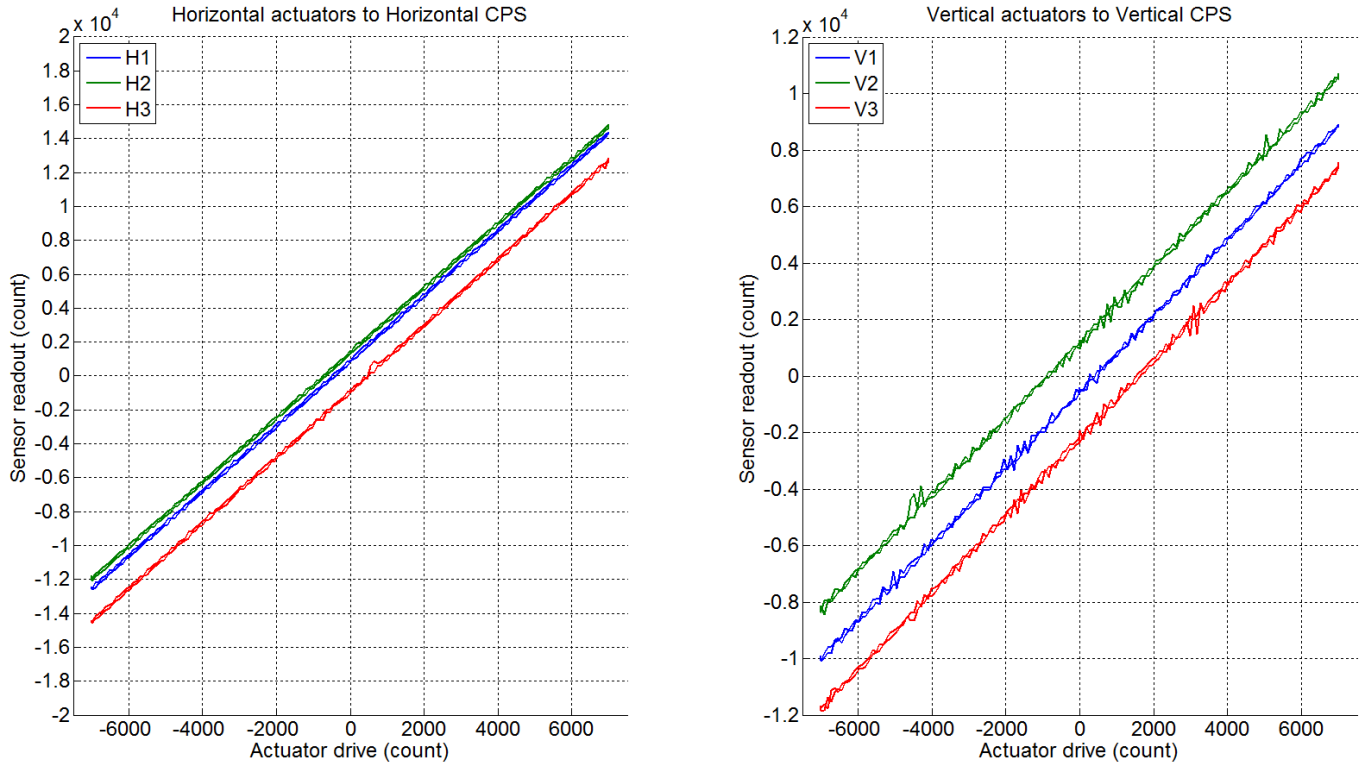


Figure - Horizontal and vertical actuators x HAM-ISI x sensors

Data files in SVN at:

seismic/HAM-ISI/L1/HAM4/Data/Linearity_Test/

- LLO_ISI_HAM4_Linearity_test_20120615.mat

Figures in SVN at:

seismic/HAM-ISI/L1/HAM4/Data/Figures/Linearity_Test/

- LLO_ISI_HAM4_Linearity_test_20120615.pdf

Acceptance criteria:

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

Issues/difficulties/comments regarding this test:
We can notice that 2 slopes barely fail the requirements, we therefore call the test waived, but performances are not worrisome here.

Test result: **Passed: __ Failed: ___ Waived: _X**

- ***Step 13- Frequency response***

Compensation filters of the new GS13 interface chassis are located in the geophone pre-filters bank.

- ***Step 13.1 - Local to local measurements***

Local to local transfer functions have been measured with 90 repetitions, before the chamber was closed.

Data files in SVN at:
seismic/HAM-ISI/L1/HAM4/Data/Transfer_Functions/Measurements/Undamped/
- LLO_ISI_HAM4_Data_TF_L2L_50mHz_500mHz_20120615-040021.mat
- LLO_ISI_HAM4_Data_TF_L2L_500mHz_5Hz_20120614-215048.mat
- LLO_ISI_HAM4_Data_TF_L2L_5Hz_200Hz_20120614-201715.mat
- LLO_ISI_HAM4_Data_TF_L2L_200Hz_800Hz_20120614-184342.mat

Data collection script files:
seismic/HAM-ISI/L1/HAM4/Scripts/Data_Collection/
- Run_Exc_Batch_L1ISIHAM4.m

Scripts files for processing and plotting in SVN at:
seismic/HAM-ISI/L1/HAM4/Scripts/Control_Scripts/
- Step_1_TF_L2L_L1_ISI_HAM4.m

Figures in SVN at:
/seismic/HAM-ISI/L1/HAM4/Data/Figures/Transfer_Functions/Measurements/Undamped/
- LLO_ISI_HAM4_TF_L2L_Raw_from_ACT_to_CPS_2012_06_15.fig
- LLO_ISI_HAM4_TF_L2L_Raw_from_ACT_to_GS13_2012_06_15.fig

Storage of measured transfer functions in the SVN at:
seismic/HAM-ISI/L1/HAM4/Data/Transfer_functions/Measurements/Undamped/
- L1_ISI_HAM4_TF_L2L_Raw_2012_06_14.mat

The local to local transfer functions are presented below.

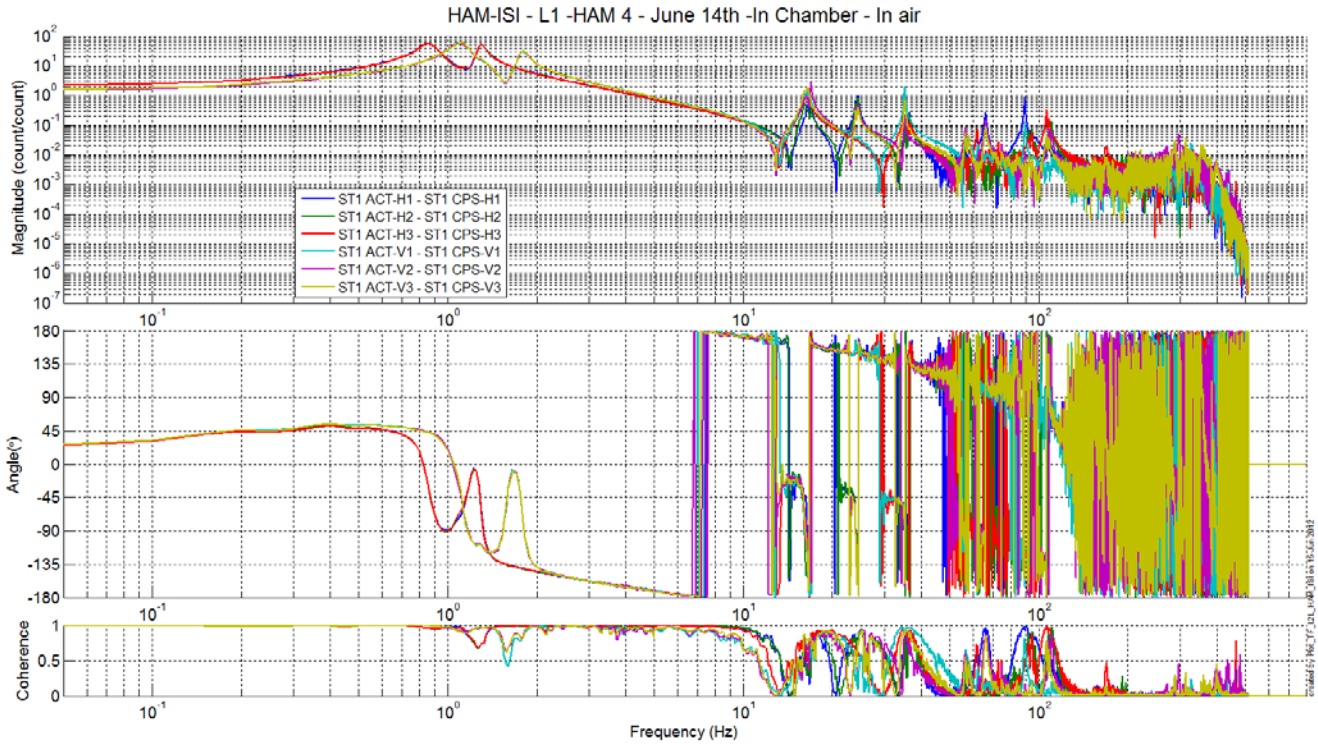


Figure - Local to Local Measurements –Capacitive Position Sensors

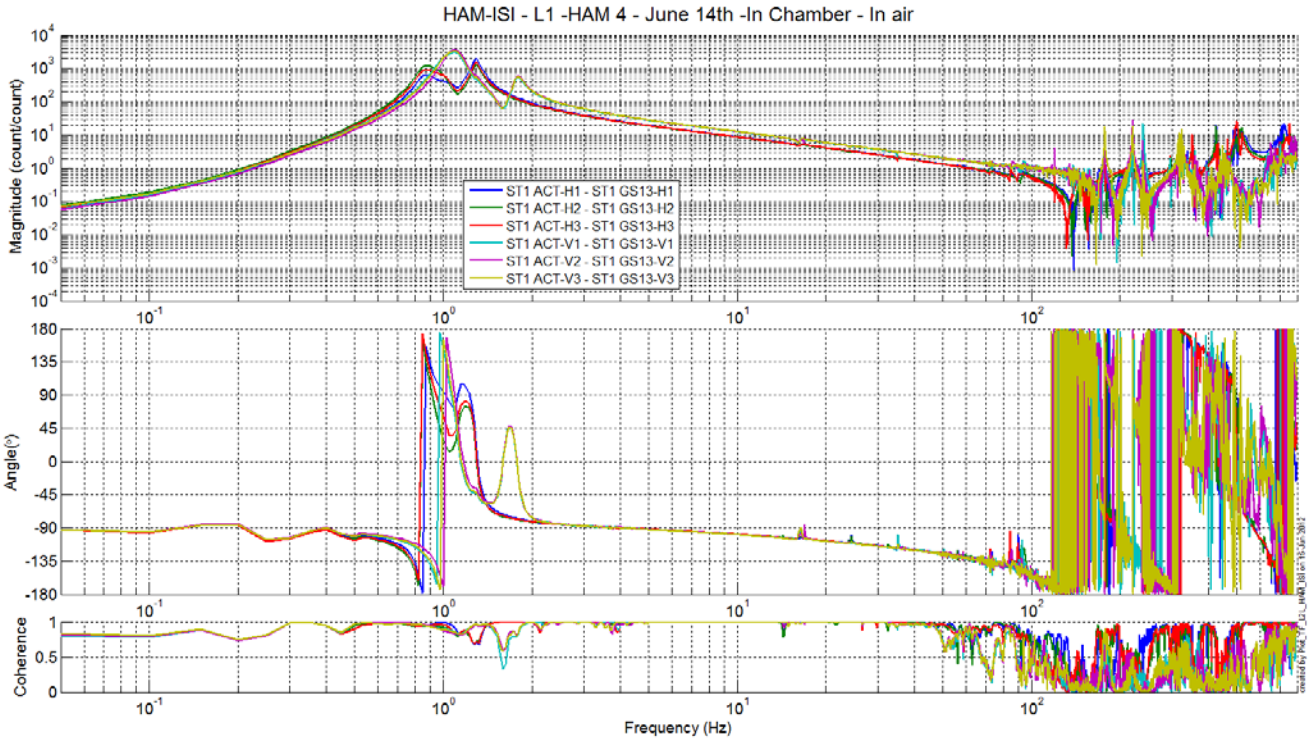


Figure - Local to Local Measurements – Inertial sensors

Conclusion of Initial In-Chamber testing

Most issues found while side-testing were solved during this phase of the testing. Very few issues were found during the testing of this unit. The known issues are summed up here:

- The Linearity test gives a slightly different slope on the H2 actuator (1.5% from average for a 1% criteria)
- We have a slight offset of 2 CPS: H1 and V3.

Issues unchanged since the Phase I testing:

- sensor gaps not recorded on the jig
- Vertical spring constant: one spring appears to have a much lower constant than the others (-8.91% than the average of the 3).