LIGO Laboratory / LIGO Scientific Collaboration

LIGO- E1000329 *LIGO* August 5th, 2011

aLIGO HAM-ISI, Pre-integration Test Report, Phase I, LLO Unit #5 (post-assembly, before storage)

E1000329 – V1

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Distribution of this document:
Advanced LIGO Project

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Introduction

This Unit#5 was built at the end of July 2011, and was tested immediately after, at the beginning of August 2011, just before switching to building BSC-ISI at LLO.

One difference of interest, it is the only unit tested on the eLIGO HAM test stand (D070395), all other units were tested on D1002124.

The procedure document used to perform this test is:

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

Other useful information can be found in:

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

I. Pre-Assembly Testing

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

Note: The back panel reads 0.508V/0.001"

S/N sensor	S/N board	ADE Gap Standoff(mm)	Location on the Jig	Gap Standoff on Jig(mm/in)	Voltage before zeroing	Voltage after zeroing. Prebake	Voltage after zeroing. Post bake
12077	NR	NR	NR	NR	NR	NR	NR
12068	NR	NR	NR	NR	NR	NR	NR
12060	NR	NR	NR	NR	NR	NR	NR
12061	NR	NR	NR	NR	NR	NR	NR
12045	NR	NR	NR	NR	NR	NR	NR
12031	NR	NR	NR	NR	NR	NR	NR

NR: not recorded

Will be measured for the next units.

Sensors noise spectra measured before baking:

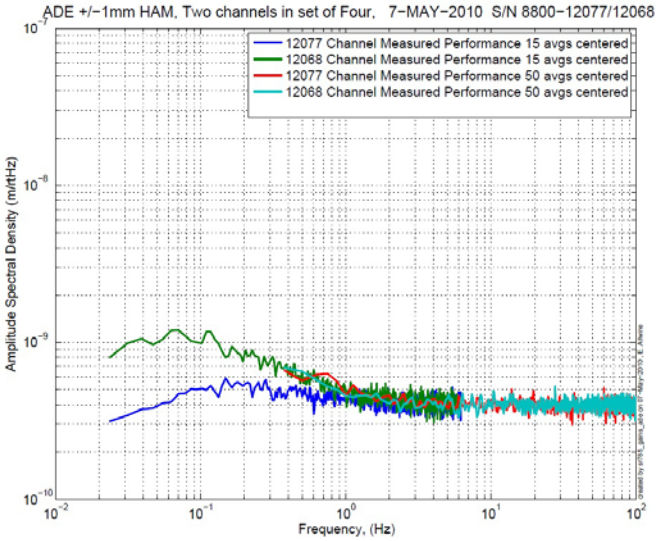


Figure - H1 and V1 sensor noise

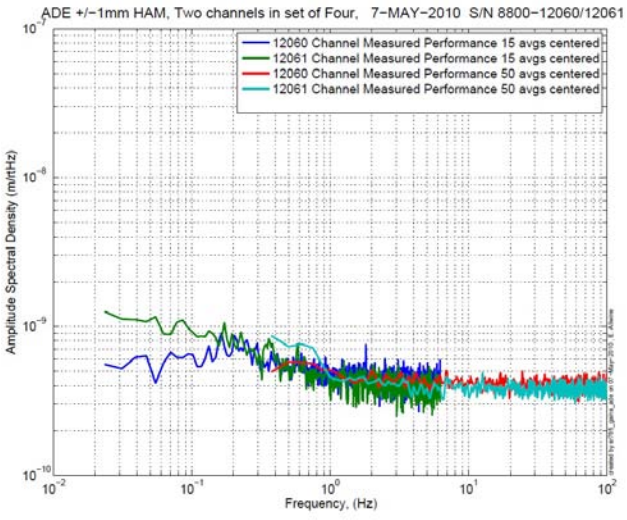


Figure - H2 and V2 sensor noise

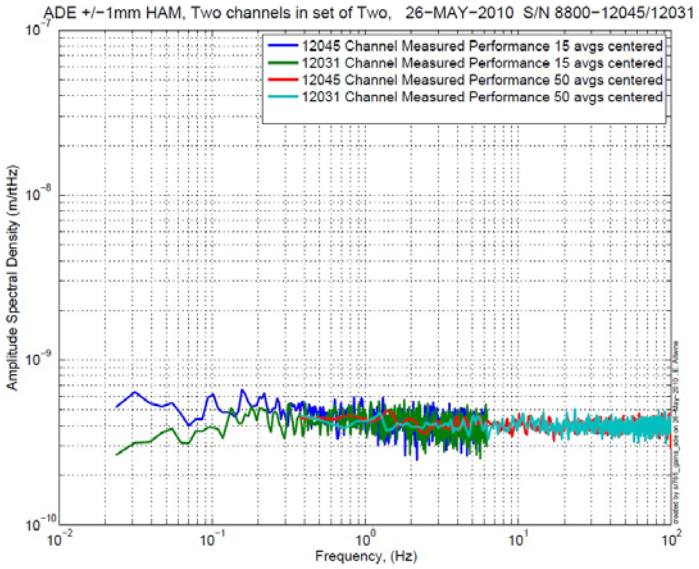


Figure - H3 and V3 sensor noise

Acceptance Criteria:

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

Issues/difficulties/comments regarding this test: Values of sensor gaps and zeroing were not recorded. 12068 and 12061 don't meet the requirements by a little at 0.1Hz, but we still decided to go on with these sensors.
H3 & V3 were originally 12010 & 12028, but while trying to set the Sensors' gap, we found an issue with V3 so we had to change them.

Test result: **Passed: __** **Failed: _X_**

- ***Step 2: GS13***

All the data related to GS-13 post podding testing can be found in the SVN at : SeismicSVN\seismic\Common\Data\aLIGO_GS13_TestData\PostMod_TestResults_PDFs. E1000058 spreadsheet provides the status of each individual GS-13 at LLO site during aLIGO HAM assembly

Data files in SVN at:
/opt/svncommon/seisvn/seismic/Common/Data/aLIGO_GS13_TestData/PostMod_TestResults_Raw ASCII

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

- gs13qatest.m

Figures in SVN at:
/opt/svncommon/seisvn/seismic/Common/Data/aLIGO_GS13_TestData/PostMod_TestResults_PDFs

- ***Step 2.1 – Horizontal GS-13s***

Huddle testing

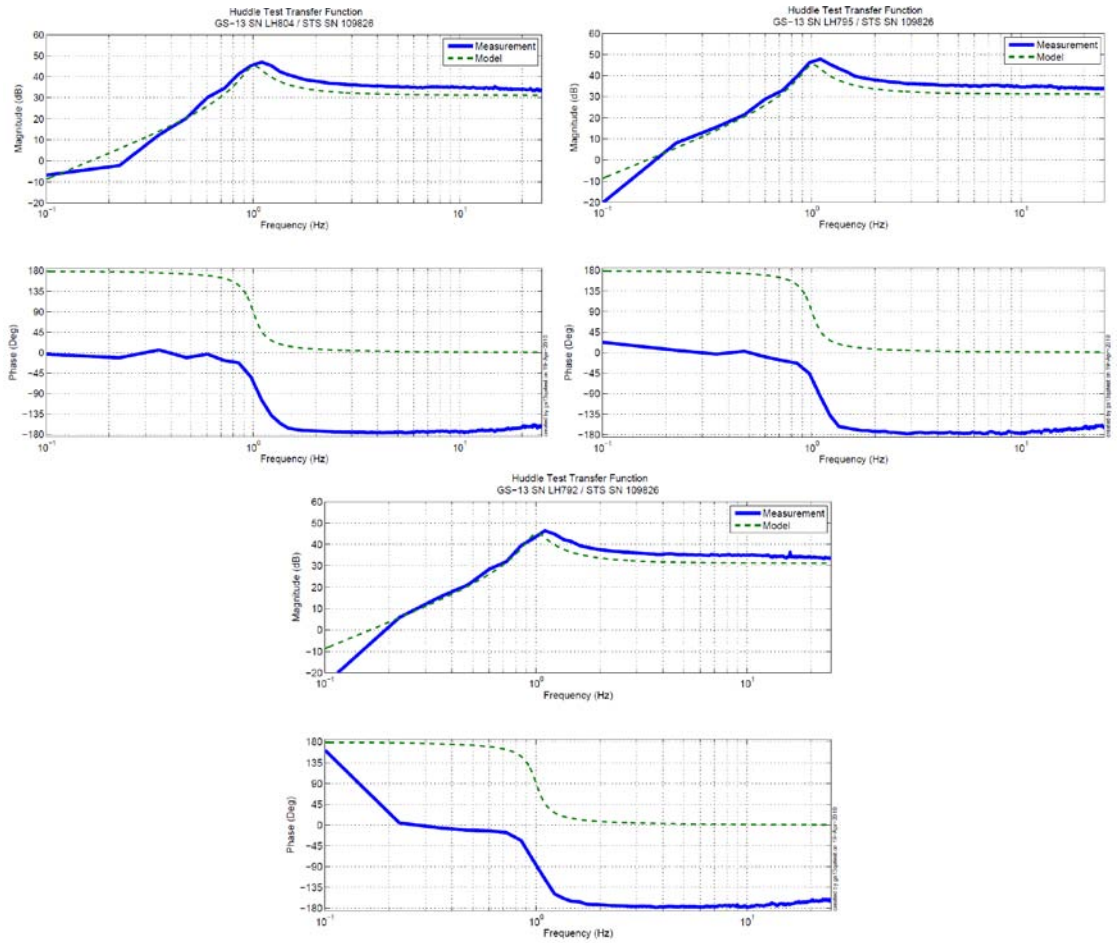


Figure - Huddle testing of Horiz GS-13 804,795, and 792 after aLIGO modifications

Step 2.2 – Vertical GS-13s

Huddle testing

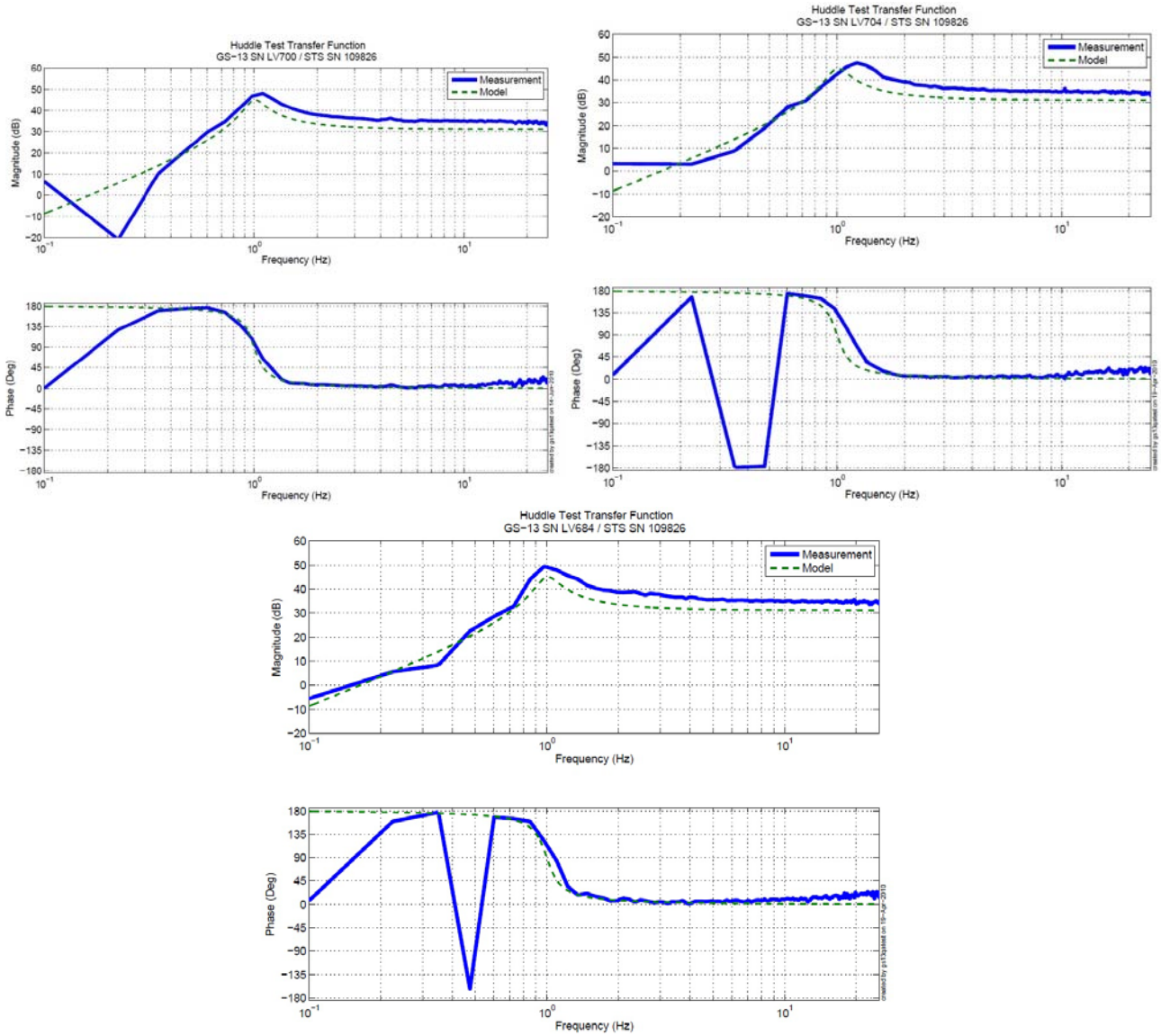


Figure - Huddle testing of Vert GS-13 700, 704 and 684 after aLIGO modifications

Driven testing

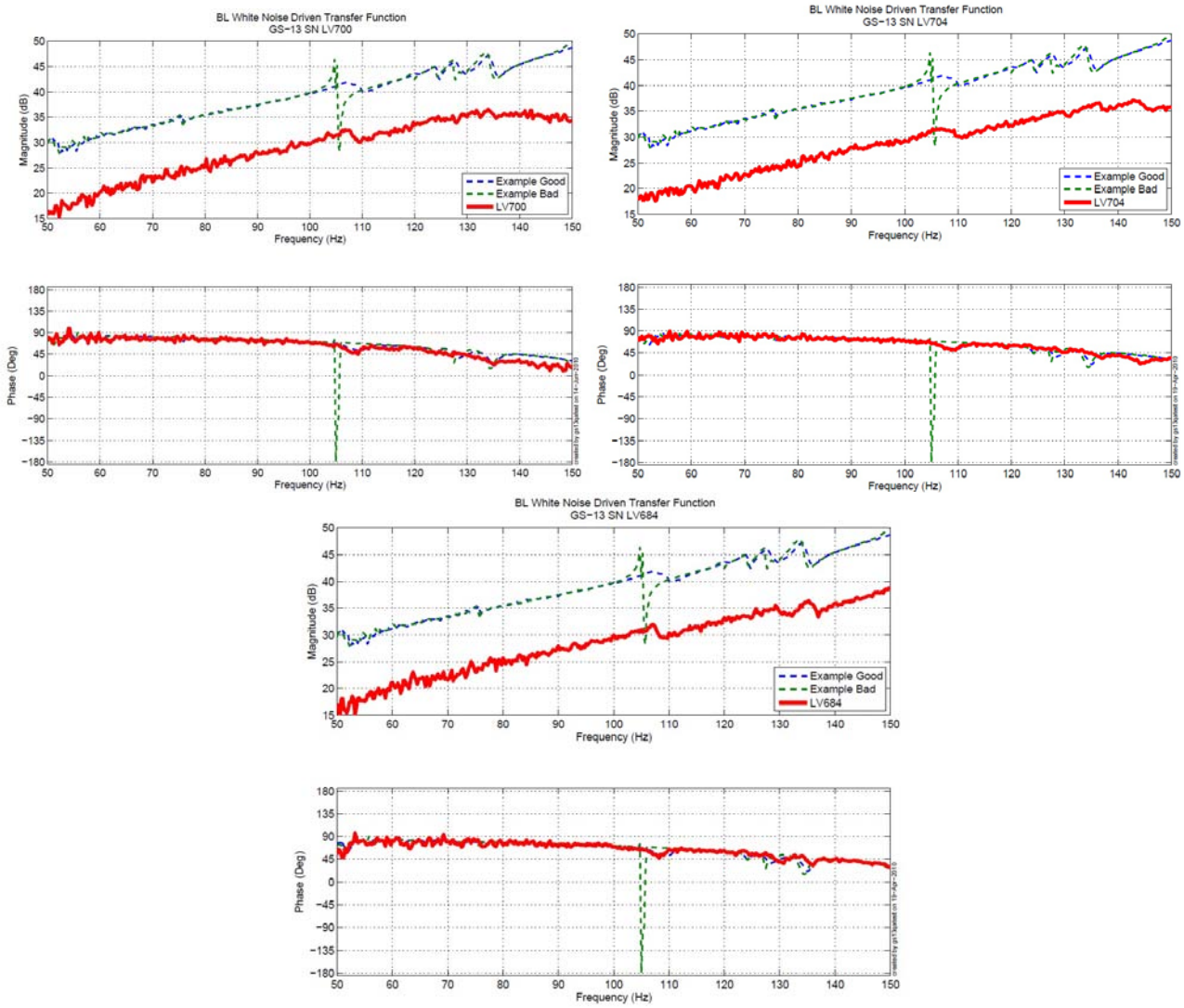


Figure - Driven Transfer Function of Vert GS-13 700, 704 and 684 after aLIGO modifications

Acceptance Criteria:

- GS13 should have been already modified and tested. GS-13 Inspection/Pod Assembly (D047810). Checklist is defined in F090070-v6
- Resonant frequency at 1 Hz (huddle testing)
- No spring resonance on vertical driven tests

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

- ***Step 3: Actuators***

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

Actuator Serial #: L030 Operator Name: Smith, Lane Date: 8/12/2009 Time: 8:58 AM Actuator Coil Resistance: 6.34 Ohms, PASS Ambient Temperature: 68.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.524 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.479	Actuator Serial #: L132 Operator Name: Gordon, Matt Date: 4/12/2010 Time: 2:29 PM Actuator Coil Resistance: 6.44 Ohms, PASS Ambient Temperature: 73.3 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.539 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.508
Actuator Serial #: L009 Operator Name: Smith, Lane Date: 8/12/2009 Time: 4:50 PM Actuator Coil Resistance: 6.37 Ohms, PASS Ambient Temperature: 72.0 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.527 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.506	Actuator Serial #: L160 Operator Name: Gordon, Matt Date: 4/14/2010 Time: 8:00 AM Actuator Coil Resistance: 6.41 Ohms, PASS Ambient Temperature: 73.3 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.526 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.508
Actuator Serial #: L148 Operator Name: Gordon, Matt Date: 4/13/2010 Time: 1:24 PM Actuator Coil Resistance: 6.33 Ohms, PASS Ambient Temperature: 73.1 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.527 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.504	Actuator Serial #: L135 Operator Name: Gordon, Matt Date: 4/12/2010 Time: 3:44 PM Actuator Coil Resistance: 6.40 Ohms, PASS Ambient Temperature: 73.3 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.533 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.503

Acceptance Criteria:

- Actuators were previously tested and results are reported in T900564.

The tests report must contain:

1- **Test results (Passed: _X_ Failed: ___)**

II. Tests to be performed during assembly

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

DCC/Vendor number	Part name	Configuration	S/N	S/N	S/N
D071001	Stage 0 base		12		
D071051	Stage 1 base		7		
D071050	Optical table				
D071002	Spring Post		38	39	36
D071100	Spring		28	19	9
D071102	Flexure		34	38	35
ADE	Position sensor	Horizontal	12077	12060	12045
		Vertical	12068	12061	12031
D047812	GS-13 pod	Horizontal	92	26	45
		Vertical	63	75	8
D047823	L4C pod	Horizontal			
		Vertical			
D0902749	Actuator	Horizontal	L030	L009	L148
		Vertical	L132	L160	L135

This unit should have L4C pods but those were not ready at the time. They will be installed before installation.

- ***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***

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***

Acceptance Criteria:

- Shim inserted won't pass between parts.

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

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

Blade #	Base (")	Tip(")	Flatness (mils)
1	0.500	0.495	+ 5
2	0.489	0.489	0
3	0.495	0.4885	+ 6.5

Table 1 - Blade profile

Acceptance Criteria:

- Blades must be flat within 0.015" inches.

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

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

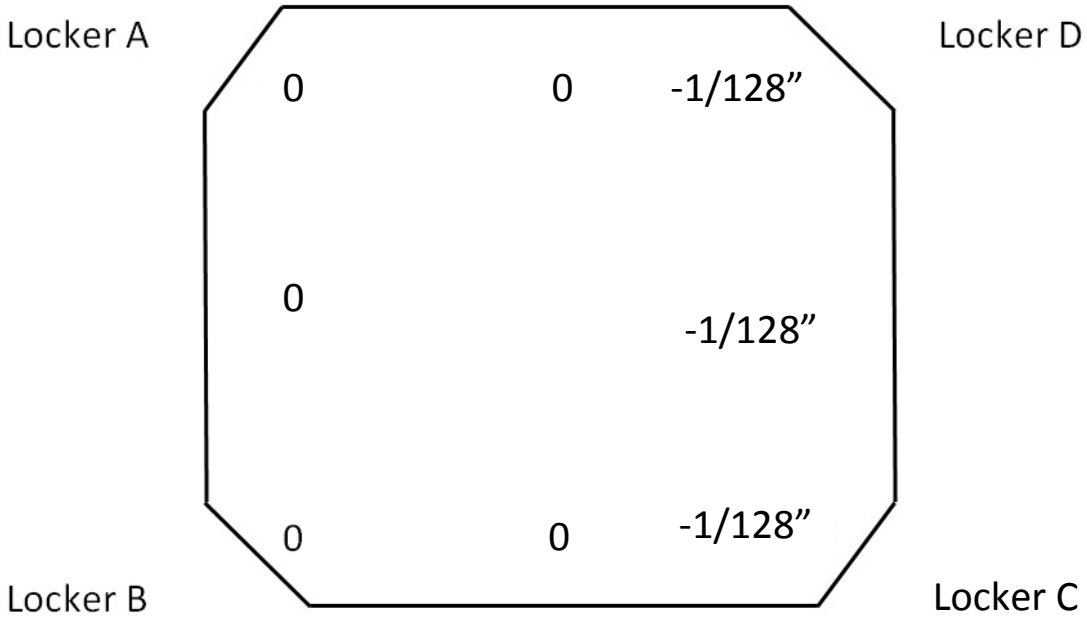
Actuator	Front Gap (1/1000")	Back Gap (1/1000")
H1	0.085	0.080
H2	0.085	0.085
H3	0.080	0.090
V1	0.085	0.085
V2	0.090	0.080
V3	0.085	0.085

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***



Max angle=(1/128)/72= 109 urad

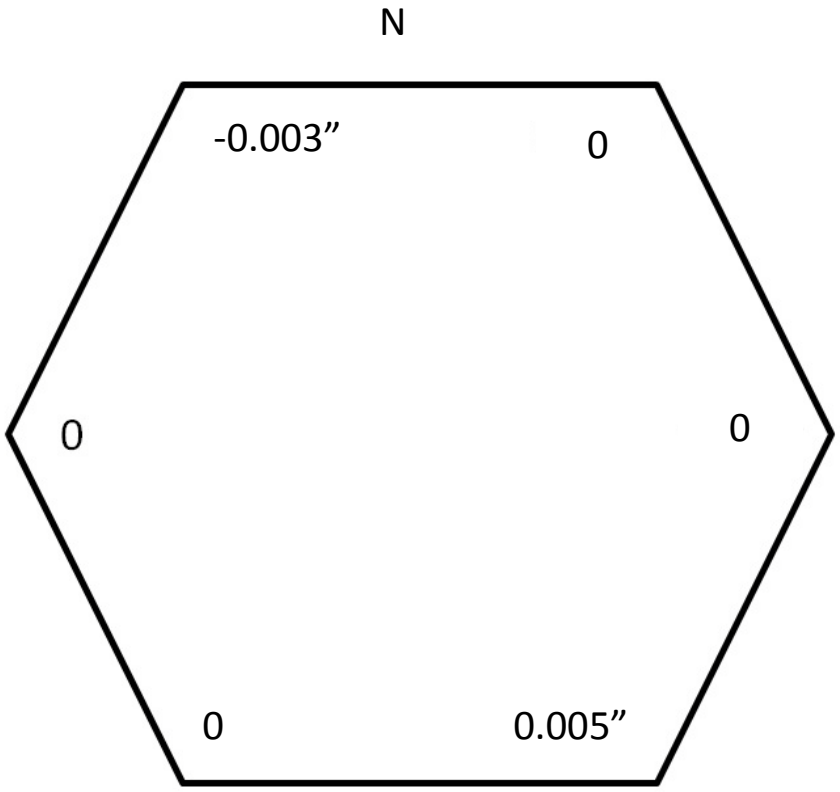
Acceptance Criteria

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

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

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

Optical Level measurement of Stage 1 at large (12 - 15) number of points.



Max angle = (0.008)/85.59= 93 urad

Acceptance Criteria

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

Test result: Passed: _X_ Failed: ___

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

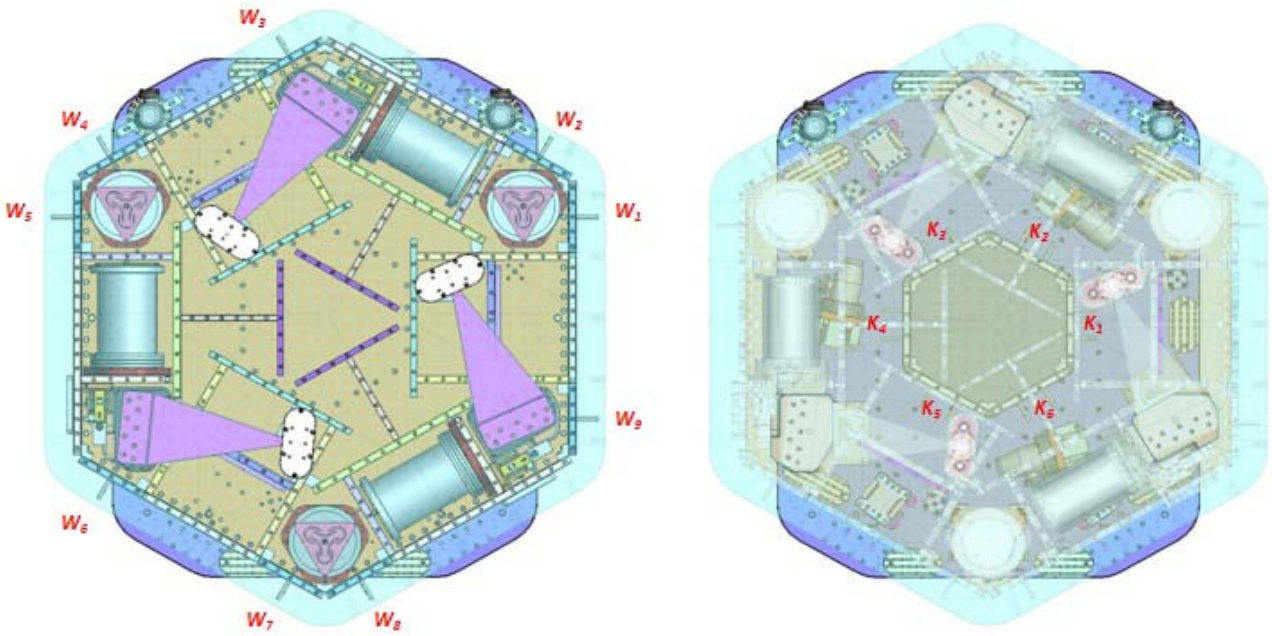


Figure – Keel Masses and Wall masses location

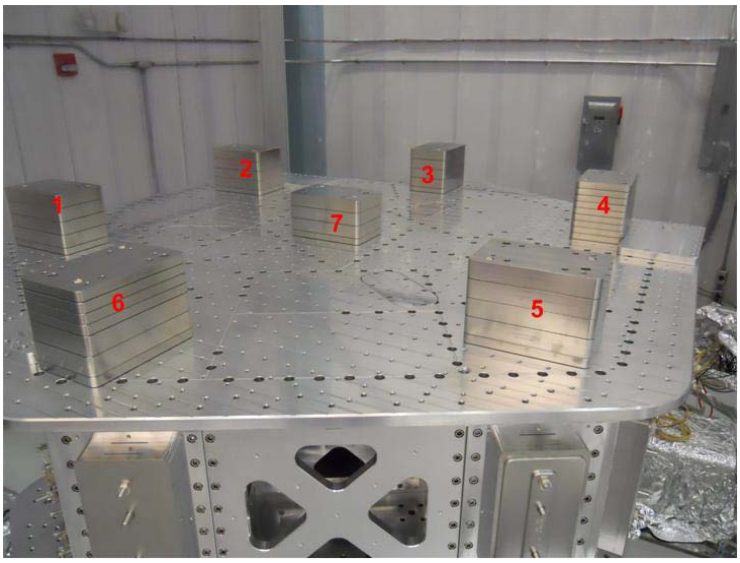


Figure - Optical table masses distribution

	Mass (kg)
t1	45.00
t2	45.00
t3	45.00
t4	45.00
t5	45.00
t6	45.00
t7	40.00
total	310.00

	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	3		55.3	25.08
w1						1	1	42.8	19.41
w2	1				1		1	35.7	16.19
w3					1		1	35.1	15.92
w4	1					1	1	43.4	19.69
w5		1				1		16.7	7.57
w6		1	1			1	1	46.1	20.91
w7			1			1	1	45	20.41
w8	1		1			1	1	45.6	20.68
Side Masses Total	4	2	3	0	3	9	7	365.7	165.88

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

	Side	Keel	Top	Total
Weigh (kg)	165.88	90.08	310.00	565.96
Torque x at O (N.m)	138.24	0.00	-9.97	128.27
Torque y at O (N.m)	116.71	5.26	11.21	133.18

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 10: Shim thickness***

Lockers	Shim thickness (mils)
A	121
B	120
C	123
D	123

Table – Shims Thickness

Acceptance Criteria

- Inventory is complete

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

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

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

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

Issues/difficulties encountered during this test : N/A

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	S1000317
		S1000316
Anti Image filter	D070081	S1000251
Anti aliasing filter	D1000269	S1000244
		S1000245
Interface chassis	D1000067	S1000311
		S1000312
		S1000314

Table - Inventory electronics

Acceptance Criteria

- Inventory is complete

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

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

	10 Kg masses at each corners		No mass		No mass	
Table locked	**ADE boxes on**		**ADE boxes on**		**ADE boxes off**	
Sensors	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Std deviation**
H1	-18.546	0.81046	-144.4	4.5063	-57.064	3.43
H2	159.56	0.78918	-279.92	3.7746	-244.34	3.21
H3	26.444	1.0285	-314.57	3.8262	*52.743*	*0.32*
V1	221.93	1.1636	525.75	2.6723	563.66	3.71
V2	-153.72	0.98618	500.2	4.969	600.5	7.74
V3	35.807	1.0338	333.44	4.1958	*52.504*	*0.27*

Capacitive position sensor readout after gap set-up

Issues/difficulties/comments regarding this test:
These measures were done when we first installed the CPS. After the LZMP test failed (Step 18), we realigned all the Vertical sensors and we didn't redo this test. We didn't redo the measurements at that point but they appear even better (which is why we "pass" that test even though it should fail because of V2 & V3 (with no masses on top)).

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 3 - Measure the Sensor gap***

Sensors	Gap measured on the Jig	Gap measured on the table
H1	NR	NR
H2	NR	NR
H3	NR	NR
V1	NR	NR
V2	NR	NR
V3	NR	NR

Acceptance criteria:

Sensors gap measured on the jig and on the optic table must be:
- 0.080" +/-0.002"

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

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

	Table locked		Table unlocked	
Sensors	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Difference**
H1	-144.4	4.5063	-84.078	15.892
H2	-279.92	3.7746	-323.9	8.623
H3	-314.57	3.8262	-127.2	13.151
V1	525.75	2.6723	287.13	9.6103
V2	500.2	4.969	773.36	13.827
`V3	333.44	4.1958	-35.496	12.264

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")

Comments:

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

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

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

	CPS read out		Calculated after calibration	
Sensors	**UP (Counts)**	**Down (Counts)**	**UP (mil)**	**Down (mil)**
V1	21149	-19148	25.5	-23.1
V2	20717	-19478	25.0	-23.5
V3	21092	-19586	25.4	-23.6
	CPS read out		**Calculated after calibration**	
Sensors	**CW(-RZ)**	**CCW (+RZ)**	**CW (mil)**	**CCW (mil)**
H1	20033	-22925	24.2	-27.7
H2	20767	-21162	25.1	-25.5
H3	22483	-21598	27.1	-26.1

Table - Optic table range of motion

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

	Push in positive direction	Push in negative direction	Railing	Actuator Gap Check
H1	23049	-25247		**X**
H2	24586	-24054		**X**
H3	24583	-23757		**X**
V1	20371	-19521		**X**
V2	32767	-32768	**X**	**X**
V3	23187	-21549		**X**

Table - Optic table range of motion

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 Spectrum***

Data files in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/ Powerspectra/Undamped
- LLO_HAM_ISI_Unit_5_Calibrated_PSD_CPS_GS13_Unlocked_Locked_2011_08_02.mat
- LLO_HAM_ISI_Unit_5_Calibrated_PSD_GS13_Table_Tilted_2011_08_02.mat

Scripts files for processing and plotting in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Data_collection/
- Powerspectra_Measurements_Locked_Unlocked_HAM_ISI.m
- - Powerspectra_Measurements_Tilted_HAM_ISI.m

Figures in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Figures/Powerspectra/Undamped
- LLO_HAM_ISI_Unit_5_Calibrated_PSD_CPS_Unlocked_Locked_2011_08_02.mat
- LLO_HAM_ISI_Unit_5_Calibrated_PSD_GS13_Unlocked_Locked_2011_08_02.mat

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

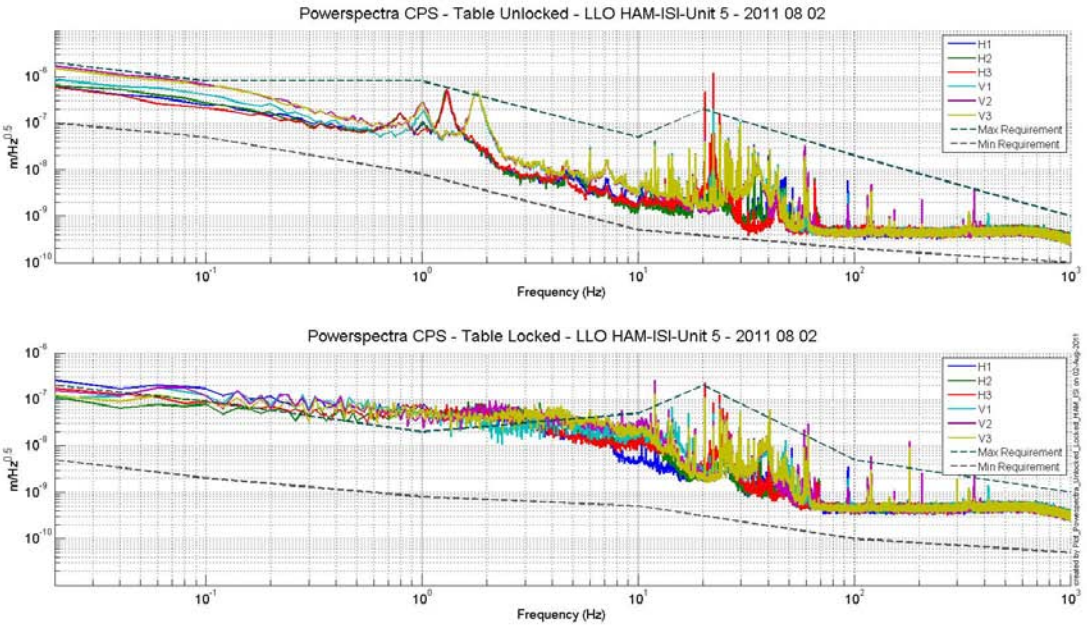


Figure - Calibrated CPS power spectrum

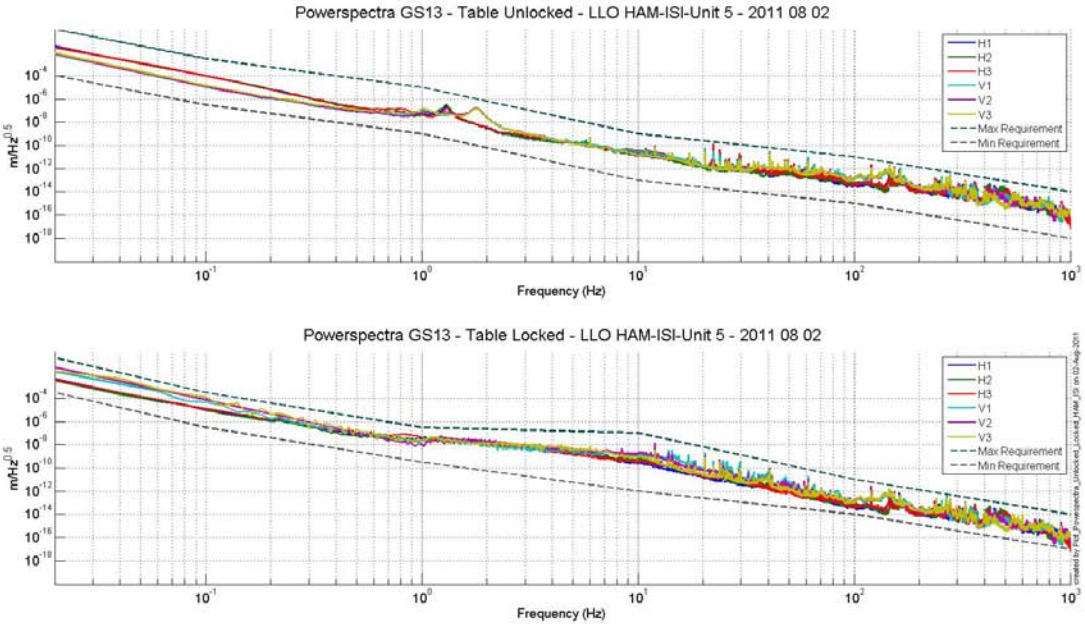


Figure – Power spectrum Calibrated GS13

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)

Sensors	ISI state	Frequency (Hz)	$2x10^{-2}$	$1x10^{-1}$	1	10	20	100	1000
GS-13	Table locked	Max	$3x10^{-1}$	$3x10^{-4}$	$3x10^{-7}$	10^{-7}		10^{-11}	10^{-14}
		Min	$3x10^{-4}$	$3x10^{-7}$	$3x10^{-10}$	10^{-12}		10^{-14}	10^{-17}
	Table unlocked	Max	1	$3x10^{-3}$	10^{-5}	10^{-9}		10^{-11}	10^{-14}
		Min	10^{-4}	$3x10^{-7}$	10^{-9}	10^{-13}		10^{-15}	10^{-18}
CPS	Table locked	Max	$2*10^{-7}$	$2x10^{-8}$	10^{-8}	$5x10^{-8}$	$2x10^{-7}$	$5x10^{-9}$	10^{-9}
		Min	$5x10^{-9}$	$2x10^{-9}$	$8x10^{-10}$	$5x10^{-10}$		10^{-10}	$5x10^{-11}$
	Table unlocked	Max	$2x10^{-6}$	$8x10^{-7}$	$8x10^{-7}$	$5x10^{-8}$	$2x10^{-7}$	$2x10^{-8}$	10^{-9}
		Min	10^{-7}	$5x10^{-8}$	$8x10^{-9}$	$5x10^{-10}$		$2x10^{-10}$	10^{-10}

Table - Step 6 -Normal conditions-Sensors power spectra requirements

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

- ***Step 7 - GS13 power spectrum -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.

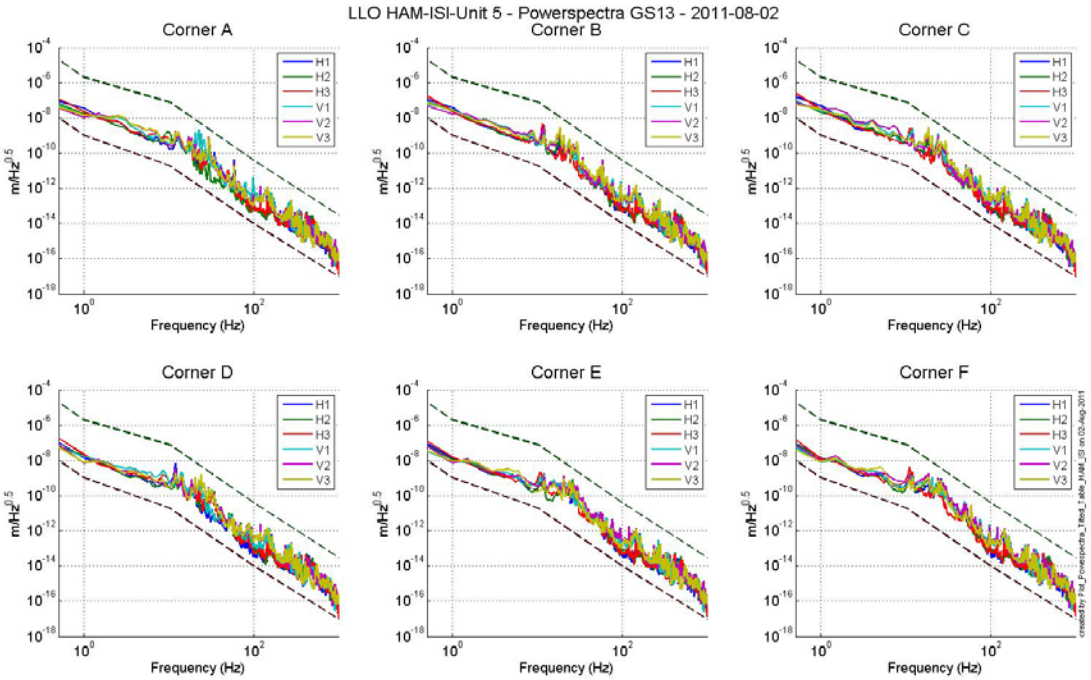


Figure – Power spectrum Calibrated GS13 with mass at corner

Data files in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_4/ Powerspectra/Undamped
- LLO_HAM_ISI_Unit_5_Calibrated_PSD_GS13_Table_Tilted_2011_08_02.mat

Scripts files for taking and processing the data, and plotting it in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Data_collection/

- Powerspectra_Measurements_Tilted_HAM_ISI.m

Figures in SVN at:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_4/Figures/ Powerspectra/Undamped
- LLO_HAM_ISI_Unit_5_Calibrated_PSD_GS13_Table_Tilted_2011_08_02.fig

Acceptance criteria:

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

Sensor	ISI State	Frequency	$5x10^{-1}$ Hz	1	10	100	1000
GS-13	Table Tilted	Max	$2x10^{--5}$	$2x10^{-6}$	$8x10^{-8}$	$4x10^{-11}$	$3x10^{-14}$
		Min	10^{-8}	10^{-9}	$2x10^{-11}$	10^{-14}	10^{-17}

Table - Table Tilted- Sensors power spectra requirements

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

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

Scripts files for taking and processing the data, and plotting it in SVN at:
seismicSVN/Common/MatlabTools

- gs13Presstest.m

Figures in SVN at:

- seismicSVN/Common/Data/Pressure_Plots

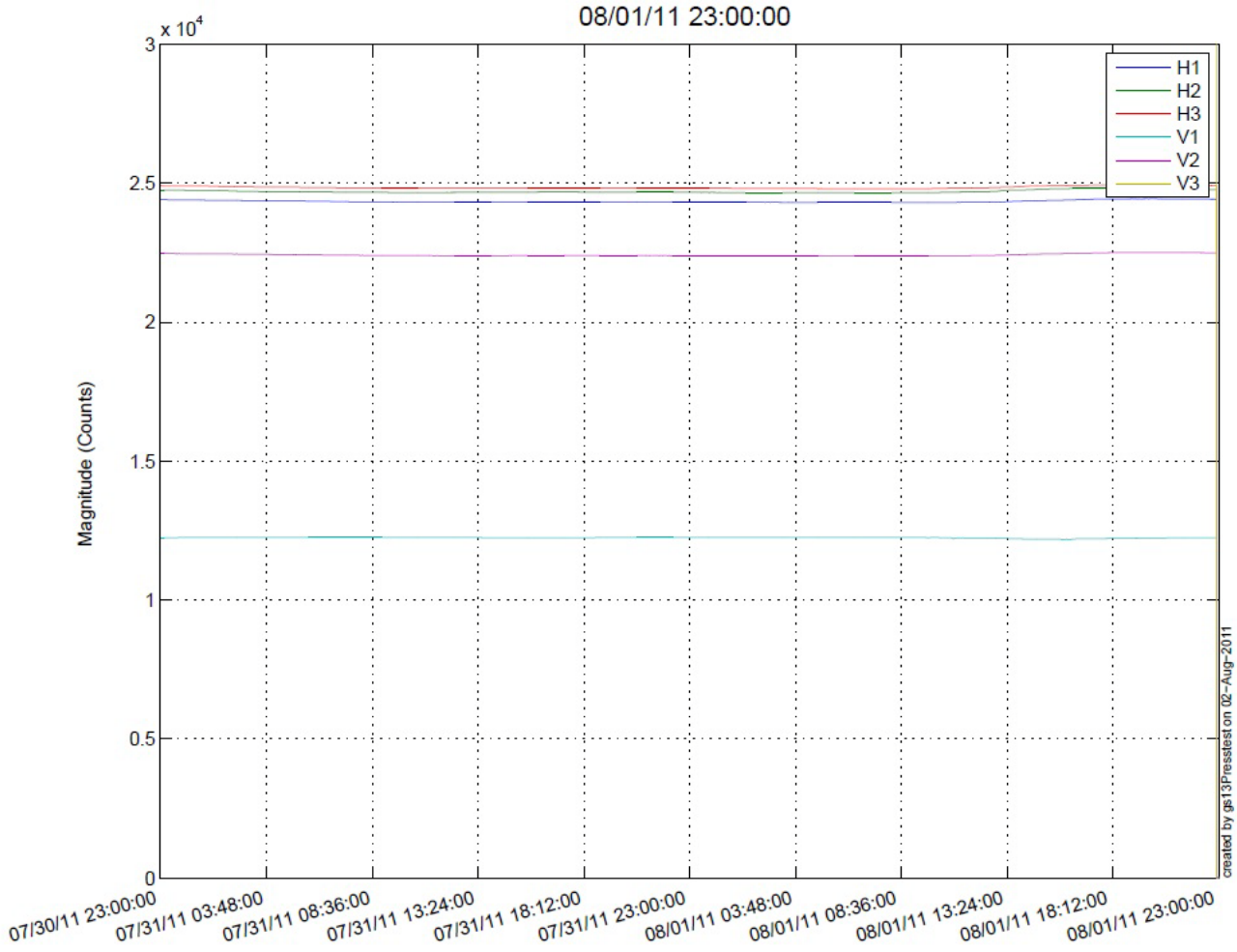


Figure – Pressure Plots

Issues/difficulties/comments regarding this test
We could not measure V1 & V3, due to an issue with the read-out electronics.

Acceptance criteria:
- The pressure on all channels must be 25000 counts +/- 3000 counts
- All channels must follow comparable trend

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

-

Step 9 - Coil Driver, cabling and resistance check

Actuator	V1		H1		V2	
Coil driver	S1000317 - Coarse 1		S1000317 - Fine 1		S1000317 - Fine 2	
Anti image pin #						
Cable #	28		25		30	
Resistance (Ohm)	P1 - P2	P2 - P3	P1 - P2	P2 - P3	P1 - P2	P2 - P3
	6.6	O.L (infinity)	6.65	O.L (infinity)	6.7	O.L (infinity)
MEDM offset (1000 counts)	Measurement P2 (-) ; P1&P3 (+)		Measurement P2 (-) ; P1&P3 (+)		Measurement P2 (-) ; P1&P3 (+)	
	0.301		0.302		0.301	

Actuator	H2		V3		H3	
Coil driver	S1000317 - Coarse 2		S1000316 - Coarse 1		S1000316 - Fine 1	
Anti image pin #						
Cable #	29		26		27	
Resistance (Ohm)	P1 - P2	P2 - P3	P1 - P2	P2 - P3	P1 - P2	P2 - P3
	6.6	O.L (infinity)	6.6	O.L (infinity)	6.5	O.L (infinity)
MEDM offset (1000 counts)	Measurement P2 (-) ; P1&P3 (+)		Measurement P2 (-) ; P1&P3 (+)		Measurement P2 (-) ; P1&P3 (+)	
	0.304		0.296		0.300	

Table - Actuators resistance check

Acceptance criteria:

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

The tests report must contain:

1- **The table "Actuators resistance check"**
2- **Issues/difficulties/comments regarding this test**
3- **Test result (Passed: _X_ Failed: ___)**

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

	Negative drive	Positive drive
H1 readout (count)	-24385	23679
H2 readout (count)	-23730	24025
H3 readout (count)	-25019	24633
V1 readout (count)	-18584	20586
V2 readout (count)	-25432	27219
V3 readout (count)	-21657	22586

Table - Range of motion - Local drive

Data files in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Static_Tests
- LLO_HAM-ISI_Unit_5_Range_Of_Motion_0801201120110801.mat

Scripts files for taking and processing the data, and plotting it in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Data_collection
- 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 11 - Vertical Sensor Calibration***

Lockers	D.I readout for a negative drive	D.I readout without any drive	D.I readout for positive drive	
A	20	0	-19.5	
B	19.5	0	-20	
C	19	0	-18.5	
D	18	0	-20	
Average	19.125	0	-19.5	**38.6**
Sensors	**Counts**	**Counts**	**Counts**	**Difference (Counts)**
V1	-14624	927.27	16781	31405
V2	-15312	768.29	17057	32369
V3	-15410	796.51	16862	32272
			Average	32015.33333

Table - Calibration of capacitive position sensors

Vertical sensitivity: 32015.3333/38.2 = 828.9 count/mil

or 828.9 count/mil * 1/1638 V/count = 0.506V/mil

or 25400nm/mil * 1/845.3 mil/count = 30.64 nm/count

Nominal Calibration

CPS Sensitivity: 20V/0.039" = 20V/39mils = 0.513V/mil

Calibration in counts: 2^{15} / 20 * 20/39 = 840 count/mil

or 25400 nm/mil * 1/840 mil/count = 30.2nm/count

Difference with Nominal sensitivity = (840-828.9)/840=-1.32%

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	7733	2.34E-04	8.40E+04	4.01E-01
V2	7760	2.34E-04	8.37E+04	4.85E-02
V3	7799	2.36E-04	8.33E+04	-4.49E-01
		Average (N/m)	8.34E+04	
		Total Stiffness (N/m)	2.51E+05	

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

The measured error on the vertical stiffness is **1.62%**

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

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

		H1	H2	H3	V1	V2	V3
Actuators (1000 counts)	**H1**	2091.6	1302.3	1342.1	-20.705	-4.32	18.172
	H2	1310.7	2061.2	1338	-11.643	-2.52	36.764
	H3	1316.9	1294.2	2096.8	7.653	53.4	40.922
	V1	178.55	155.66	-346.54	1434.3	-31.91	-577.77
	V2	-368.96	175.17	168.61	-635.23	1457.4	-45.395
	V3	195.88	-384.09	188.23	-4.448	-629.94	1503.8

Table - Main and cross coupling

Data files in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Static_Tests

- LLO_HAM_ISI_Unit_5_Sensor_Readout_Local_20110801.mat

Scripts files for taking data in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Data_Collection

- Sensor_Readout_Local_Drive_MEDM_HAM_ISI.m

Issues/difficulties/comments regarding this test:

Acceptance criteria:

- **Vertical**
  For a +1000 count offset drive on vertical actuators
  - Collocated sensors must be 1400 counts +/- 10%

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

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

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

	Slope	Offset	Average slope	Variation from average (%)
H1	2.105	-789	2.0883	0.80
H2	2.073	-131		-0.73
H3	2.087	-400		-0.06
V1	1.461	185	1.4680	-0.48
V2	1.472	492		0.27
V3	1.471	-359		0.20

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

Scripts files for taking data in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Data_Collection

- Linearity_Test_Awgstream_HAM_ISI.m

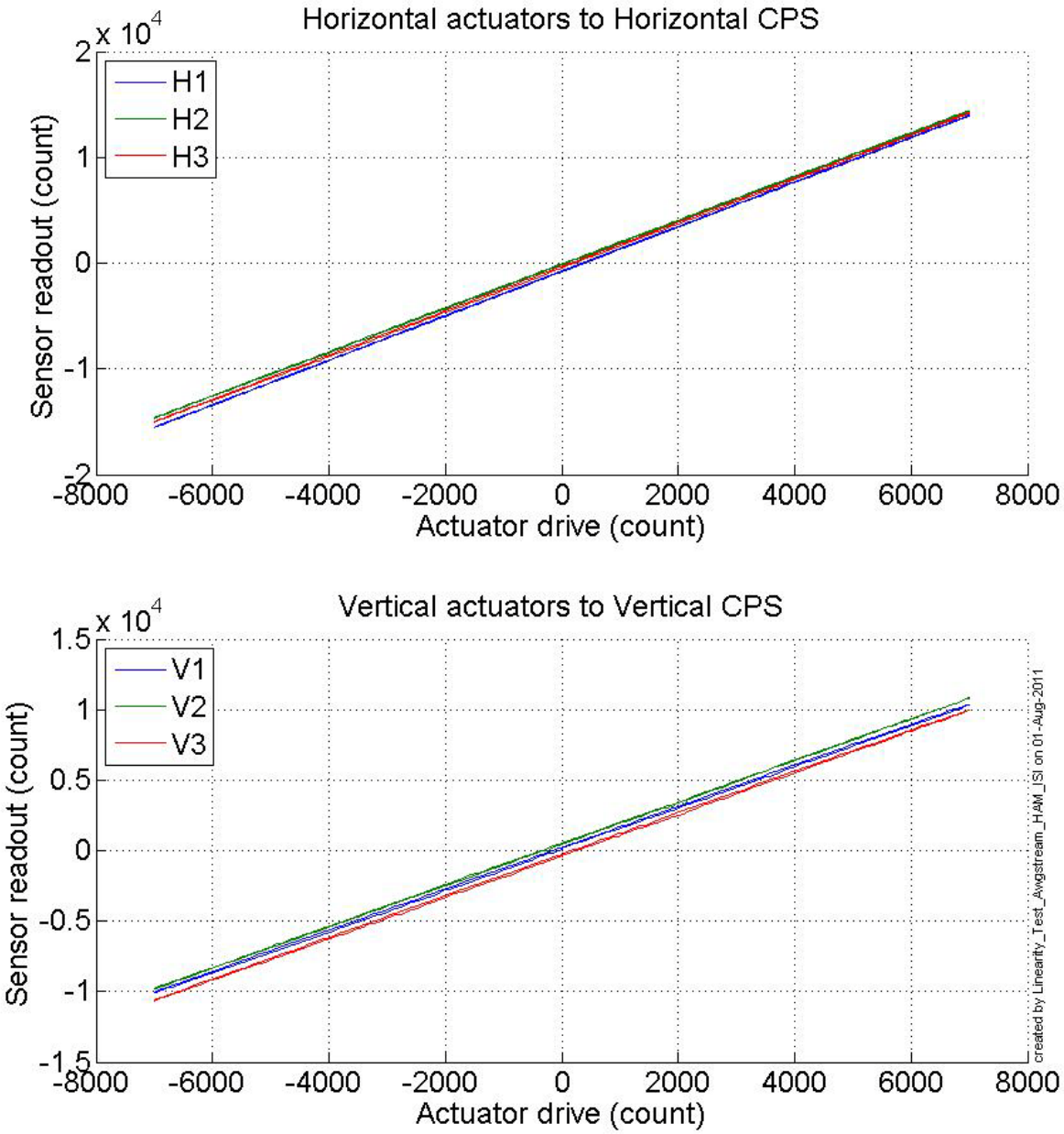


Figure - Horizontal and vertical actuators x HAM-ISI x sensors

Data files in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Linearity_test

- LLO_HAM_ISI_Unit_5_Linearity_test_20110801.mat

Figures in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Figures/Linearity_test

- LLO_HAM_ISI_Unit_5_Linearity_test_20110801.fig
- LLO_HAM_ISI_Unit_5_Linearity_test_20110801.pdf

Acceptance criteria:

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

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

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

Sensors readout (count)	1000 counts drive	X Drive	Y Drive	Z Drive	Rx Drive	Ry Drive	Rz Drive
	H1	453.79	-255.31	201.69	-265.31	-52.31	-1840.3
	H2	466.55	652.17	212.55	663.34	-30.45	-1817.5
	H3	-293.7	165.3	182.3	173.3	673.2	-1827.7
	V1	-39.719	-17.603	262.88	-496.82	-1632.8	0.1409
	V2	1.693	9.493	284.39	1718	403.39	-0.307
	V3	6.04	-13.96	251.14	-1244	1237.4	-7.96
	Direction read out	511.15	516.76	245.03	2641.4	2528.6	3096.1

Table - Tests in the general coordinate basis

Issues/difficulties/comments regarding this test:

Acceptance criteria:

Sensors readout (count)	X Drive	Y Drive	Z Drive	Rx Drive	Ry Drive	Rz Drive
H1	+	-				-
H2	+	+				-
H3	-	0				-
V1			+	-	-	
V2			+	+	+	
V3			+	-	+	
Direction read out	+	+	+	+	+	+

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

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

- ***Step 16- Frequency response***

Compensation filters of the new GS13 interface chassis are located in the geophone pre-filters bank. Powerspectra were measured with masses on the optic table not bolted.

- ***Step 16.1 - Local to local measurements***

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

Data files in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Transfer_Functions/Measurements/
Undamped/

- LLO_HAM_ISI_Unit_5_Data_TF_L2L_50mHz_500mHz_20110730-220432.mat
- LLO_HAM_ISI_Unit_5_Data_TF_L2L_500mHz_5Hz_20110730-185911.mat
- LLO_HAM_ISI_Unit_5_Data_TF_L2L_200Hz_800Hz_20110730-155229.mat
- LLO_HAM_ISI_Unit_5_Data_TF_L2L_5Hz_200Hz_20110730-172550.mat

Data collection script files:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Data_Collection

- Run_TF_L2L_50mHz_500mHz.m
- Run_TF_L2L_500mHz_5Hz.m
- Run_TF_L2L_5mHz_200Hz.m
- Run_TF_L2L_200Hz_800Hz.m

Scripts files for processing and plotting in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Transfer_Functions/Measurements/
Undamped/

- Plot_LLO_HAM_ISI_Unit_5_TF_L2L_2011_08_02.m

Figures in SVN at:
opt/svncommon/seisvn/seismic/HAMISI/X2/Data/Unit_4/Figures/Transfer_Functions/Measurements/
Undamped/

- LLO_HAM_ISI_Unit_5_TF_L2L_H_CPS_50mHz_800Hz_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_L2L_V_CPS_50mHz_800Hz_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_L2L_H_GS13_50mHz_800Hz_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_L2L_V_GS13_50mHz_800Hz_2011_08_02.fig

Storage of measured transfer functions in the SVN at:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_4/Transfer_functions/ Measurements/
Undamped/

- LLO_HAM_ISI_Unit_5_Data_TF_L2L_2011_08_02.mat

The local to local transfer functions are presented below.

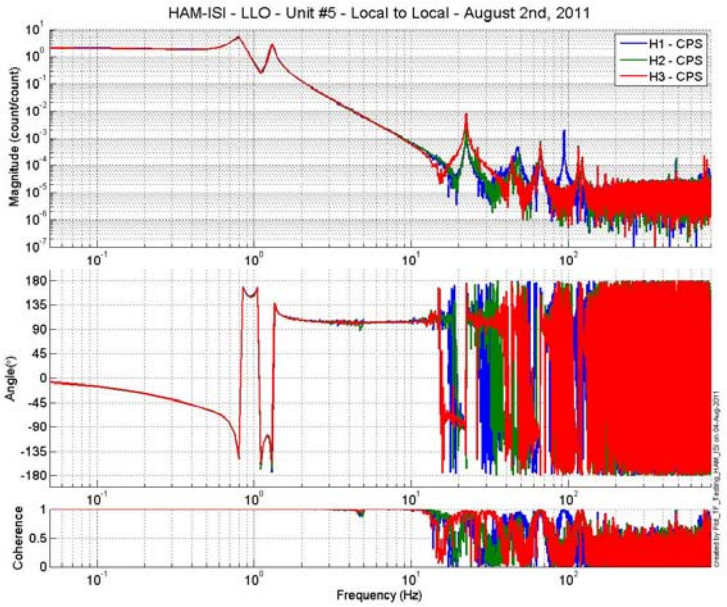


Figure - Local to Local Measurements – Horizontal capacitive sensors

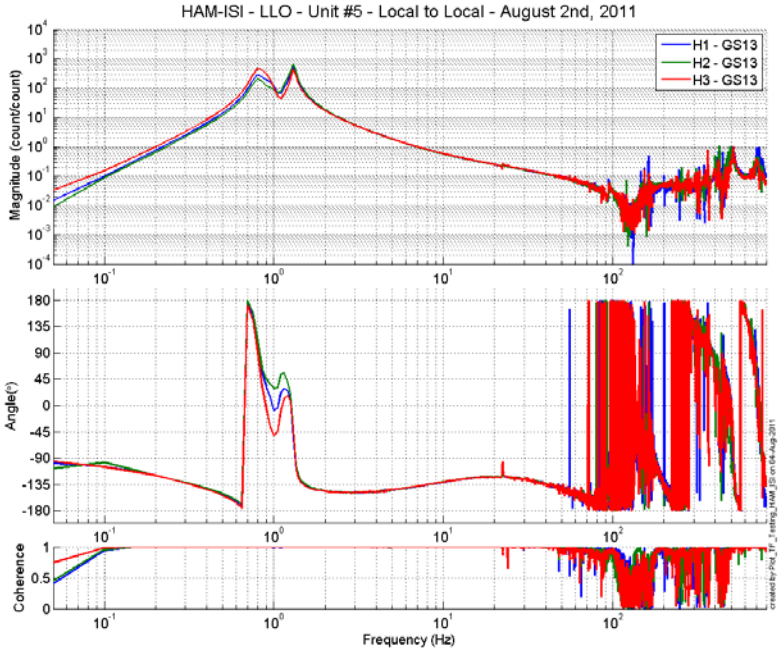


Figure - Local to Local Measurements – Horizontal inertial sensors

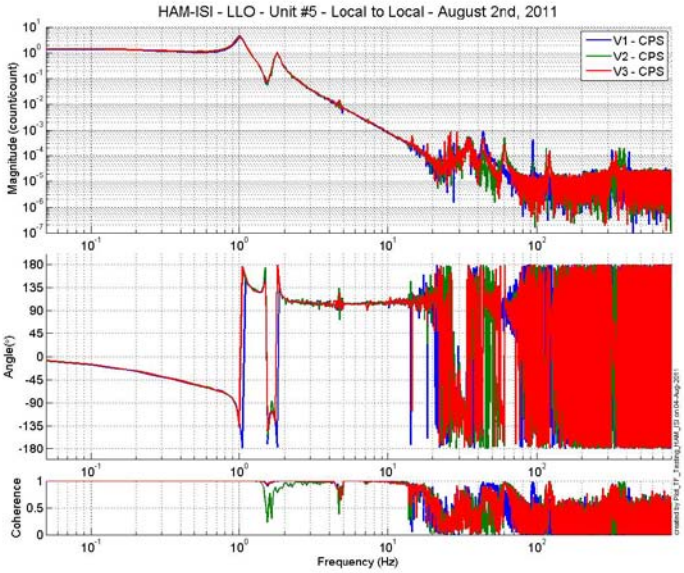


Figure - Local to Local Measurements – Vertical capacitive sensors

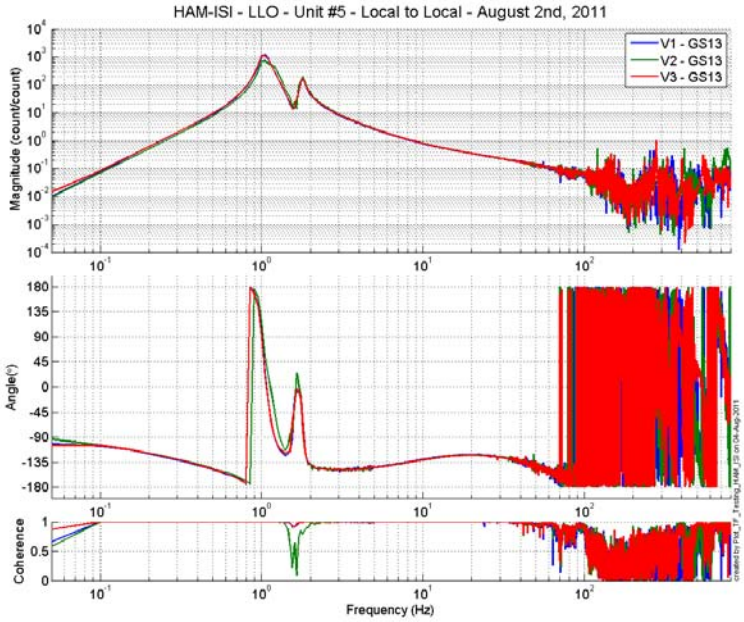


Figure - Local to Local Measurements – Vertical inertial sensors

Issues/difficulties/comments regarding this test:
Around 1 Hz, the inertial sensors seem to indicate different behaviors of each corner.

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

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

Data files in SVN at:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Transfer_Functions/Measurements/Undamped/

- LLO_HAM_ISI_Unit_5_Data_TF_C2C_50mHz_500mHz_20110731-072146.mat

- LLO_HAM_ISI_Unit_5_Data_TF_C2C_500mHz_5Hz_20110731-041625.mat
- LLO_HAM_ISI_Unit_5_Data_TF_C2C_5Hz_200Hz_20110731-024304.mat
- LLO_HAM_ISI_Unit_5_Data_TF_C2C_200Hz_800Hz_20110731-010943.mat

Scripts files for processing and plotting in SVN at:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Transfer_Functions/Measurements/Undamped/

- Plot_LLO_HAM_ISI_Unit_5_TF_C2C_2011_08

Figures in SVN at:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Figures/Transfer_Functions/Measurements/Undamped/

- LLO_HAM_ISI_Unit_5_TF_C2C_Z_RX_RY_CPS_50mHz_800Hz_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_C2C_X_Y_RZ_GS13_50mHz_800Hz_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_C2C_Z_RX_RY_CPS_50mHz_800Hz_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_C2C_Z_RX_RY_GS13_50mHz_800Hz_2011_08_02.fig

Storage of measured transfer functions in the SVN at:
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_4/Transfer_functions/Measurements/Undamped

- LLO_HAM_ISI_Unit_5_Data_TF_C2C_2011_08_02

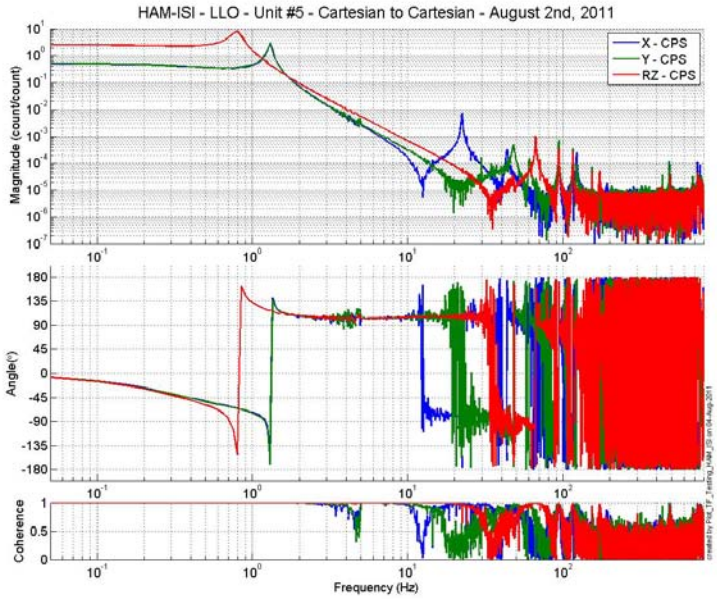


Figure - Cartesian to Cartesian CPS measurements – X, Y, RZ directions

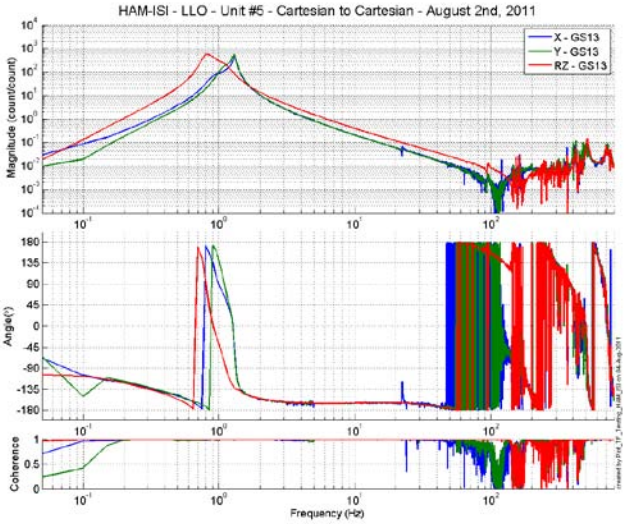
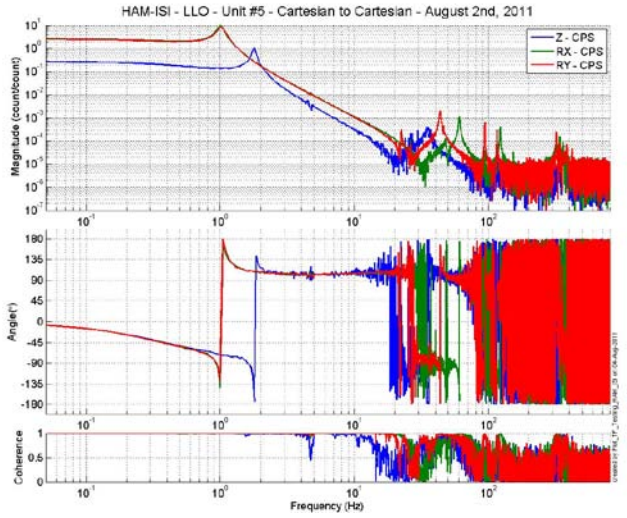


Figure - Cartesian to Cartesian GS-13 measurements – X, Y, RZ directions



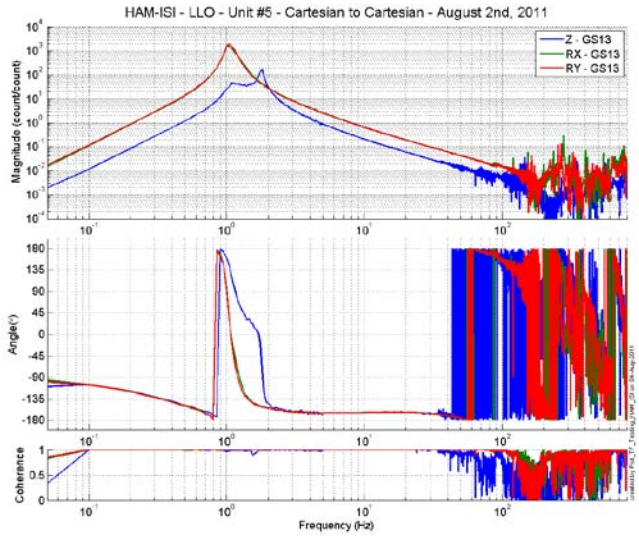


Figure - Cartesian to Cartesian measurements – Z, RX, RY directions

Issues/difficulties/comments regarding this test:
We can notice a resonance at 11 Hz on the X direction that does not exist on the model. This is likely to be due to the different stand (actual support tubes here) used to support this ISI. This seems consistent with in vacuum HAM 6 results.

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***

This is the 2nd unit which is compared to LHO Unit #2 instead of LLO HAM 6 (v4 was comparing to LLO HAM 6 and both data can be found on the SVN).

Scripts files for processing and plotting in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Transfer_Functions/Measurements/Undamped/

- Plot_LLO_HAM_ISI_Unit_5_TF_L2L_2011_08_02

Local to local figures in SVN at:
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Figures/Transfer_Functions/Measurements/Undamped

- LLO_HAM_ISI_Unit_5_TF_L2L_H_CPS_50mHz_800Hz_wRef_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_L2L_V_CPS_50mHz_800Hz_wRef_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_L2L_H_GS13_50mHz_800Hz_wRef_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_L2L_V_GS13_50mHz_800Hz_wRef_2011_08_02.fig

GS13, Local to local measurement

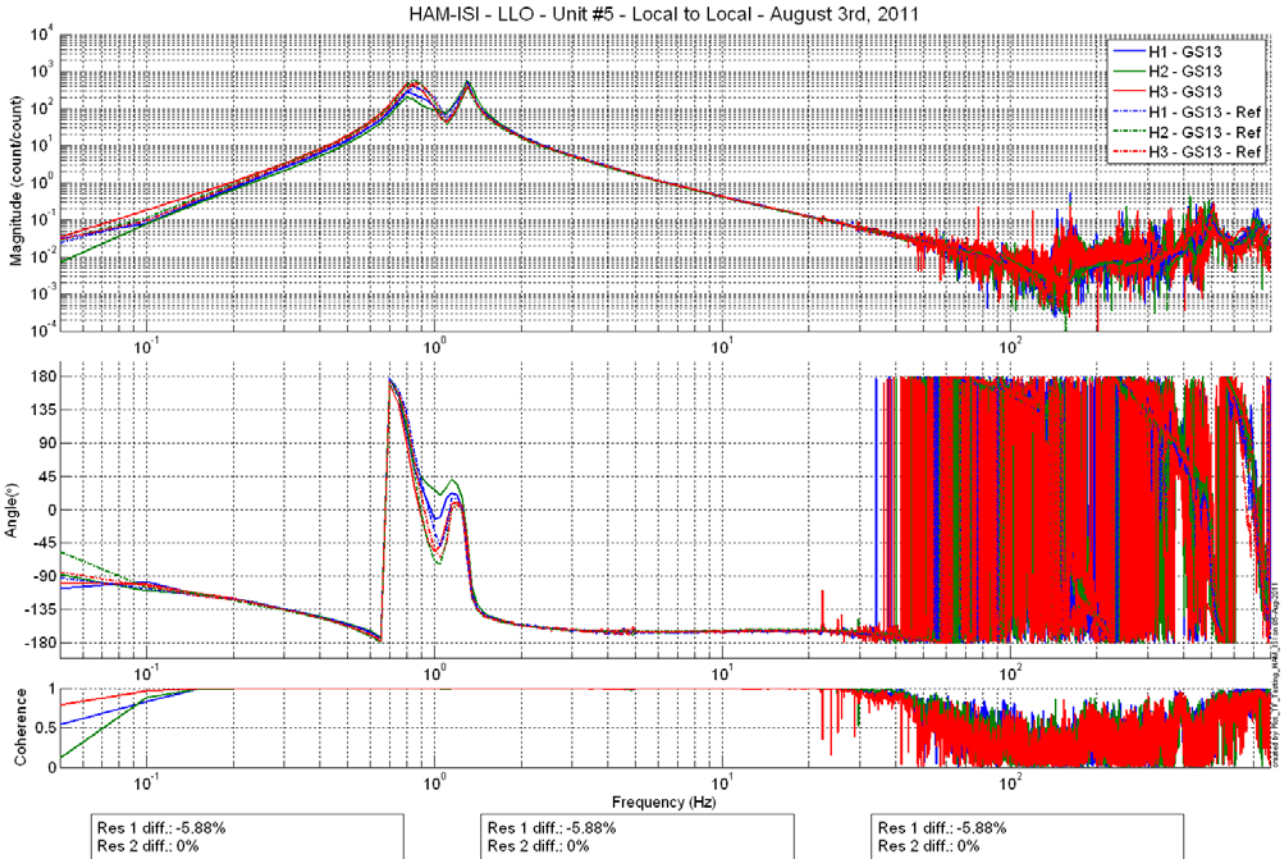


Figure - Local to local measurements comparison with LHO UNIT 2 – Horizontal GS-13

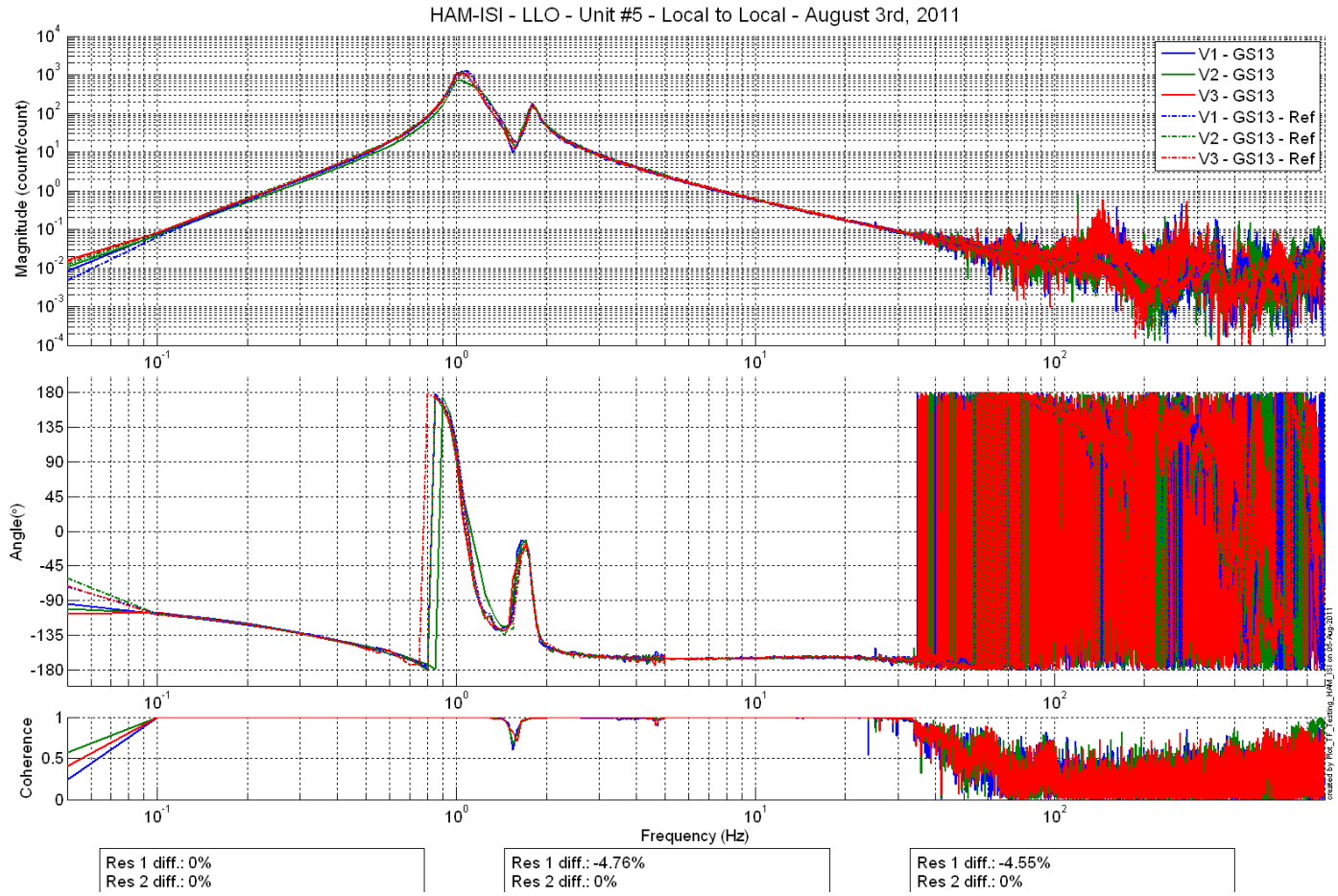


Figure - Local to local measurements comparison with LHO UNIT 2 – Vertical GS13

CPS, Local to local measurement, Undamped

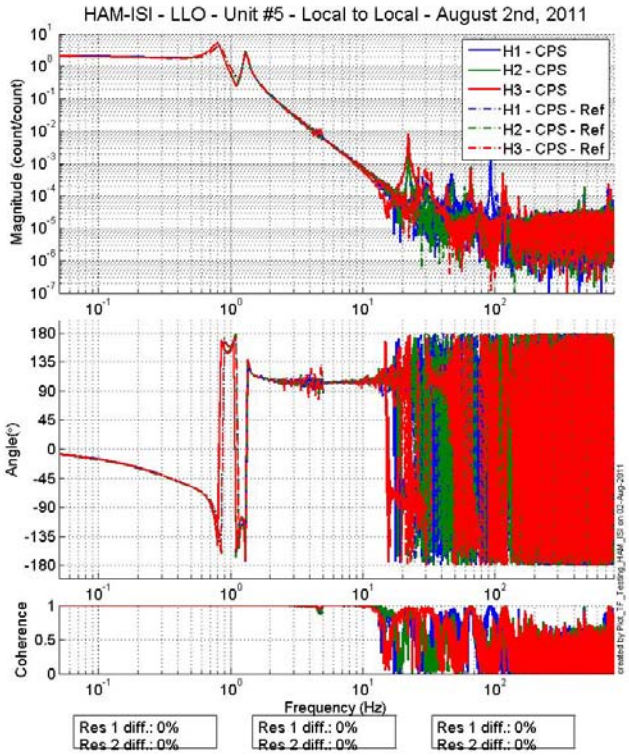


Figure - Local to local measurements comparison – Horizontal Position sensors

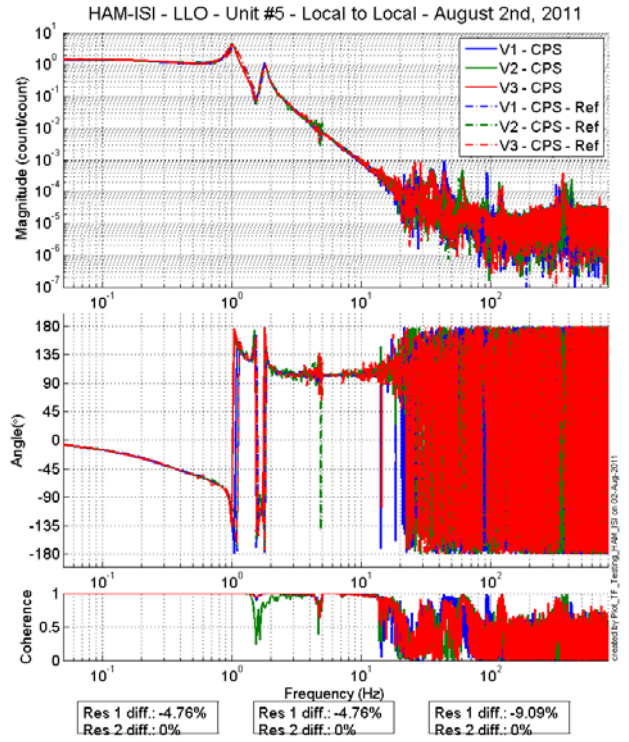


Figure - Local to local measurements comparison – Vertical Position sensors

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

Scripts files for processing and plotting in SVN at:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Transfer_Functions/Measurements/Undamped/

- Plot_LLO_HAM_ISI_Unit_5_TF_C2C_2011_08_02.m

Cartesian to Cartesian figures in SVN at :
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Figures/Transfer_functions/Measurements/Undamped

- LLO_HAM_ISI_Unit_5_TF_C2C_X_Y_RZ_CPS_50mHz_800Hz_wRef_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_C2C_X_Y_RZ_GS13_50mHz_800Hz_wRef_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_C2C_Z_RX_RY_CPS_50mHz_800Hz_wRef_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_TF_C2C_Z_RX_RY_GS13_50mHz_800Hz_wRef_2011_08_02.fig

GS13, Cartesian to Cartesian measurement, Undamped

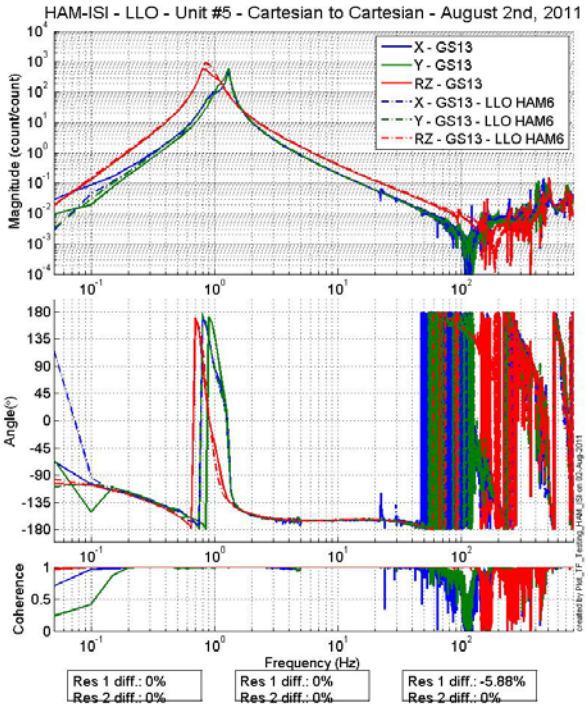


Figure - Cartesian to Cartesian measurements comparison with LHO Unit2 – Horiz GS13

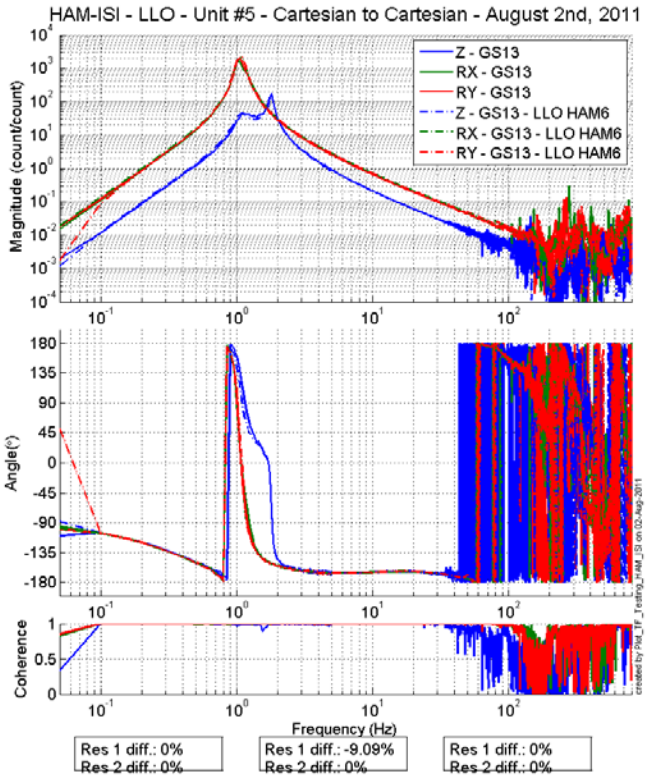


Figure - Cartesian to Cartesian measurements comparison with LHO Unit2 – Vertical GS13

CPS, Cartesian to Cartesian measurement, Undamped

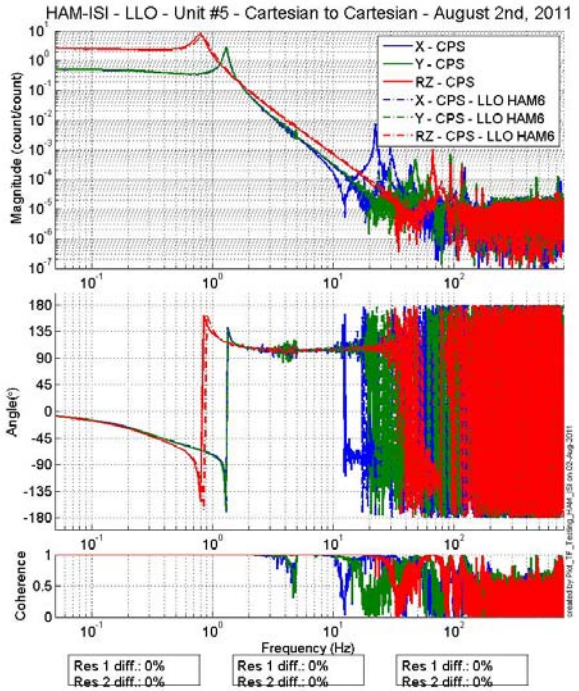


Figure - Cartesian to Cartesian measurements comparison with LHO Unit2 – Horizontal Position sensors

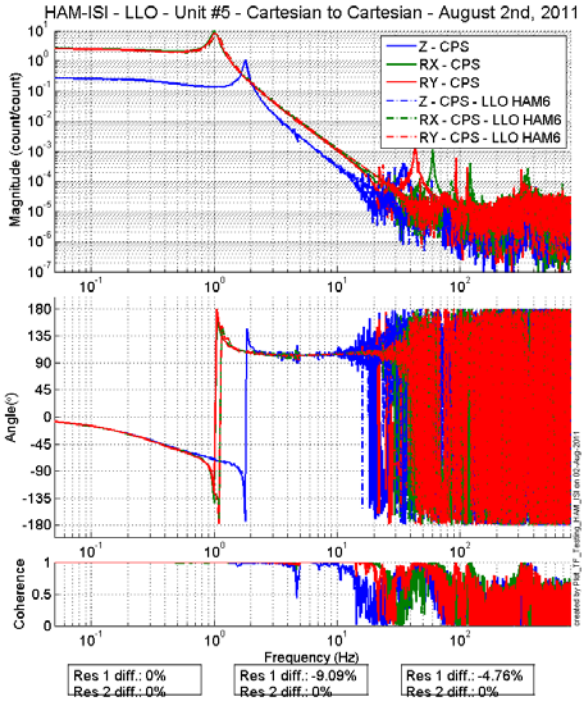


Figure - Cartesian to Cartesian measurements comparison with LHO Unit2 – Vertical Position sensors

Issues/difficulties/comments regarding this test

In order to get matching results with LHO Unit #2, we had to have the L2L transfer functions taken this way:

- CPS sensors TF: with the "comp" filters engaged in the pre-filters bank of the GS-13
- GS-13 sensors TF: with the "comp" filters engaged right next to the damping loops in the damping path, which seems a problem because here we're filter the excitation.

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:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Data_Collection

- Run_Cart2Cart_10mHz_100mHz.m

Data files in SVN at:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Transfer_Functions/Measurements/Undamped/

- LZMP_LLO_HAM-ISI-Unit_5_2011_08_02.mat

Scripts files for processing and plotting in SVN at:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Transfer_Functions/Measurements/Undamped/

- LZMP_2011_08_02.m

Figures in SVN at:
opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Figures/Transfer_Functions/Measurements/Undamped/

- LZMP.fig

X & Y offsets:

X offset (mm)	**9.7693**
Y offset (mm)	**1.0929**

Table – Offset of the Lower Zero Moment Plane

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

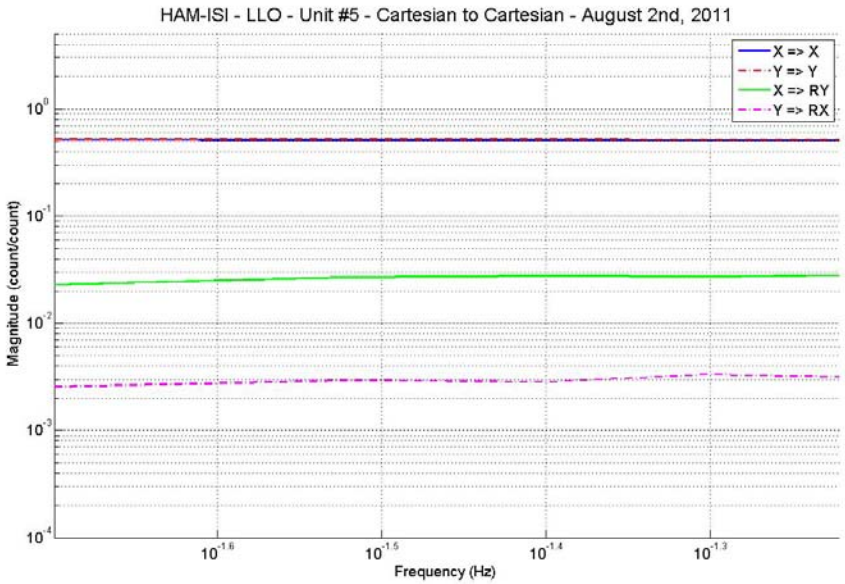
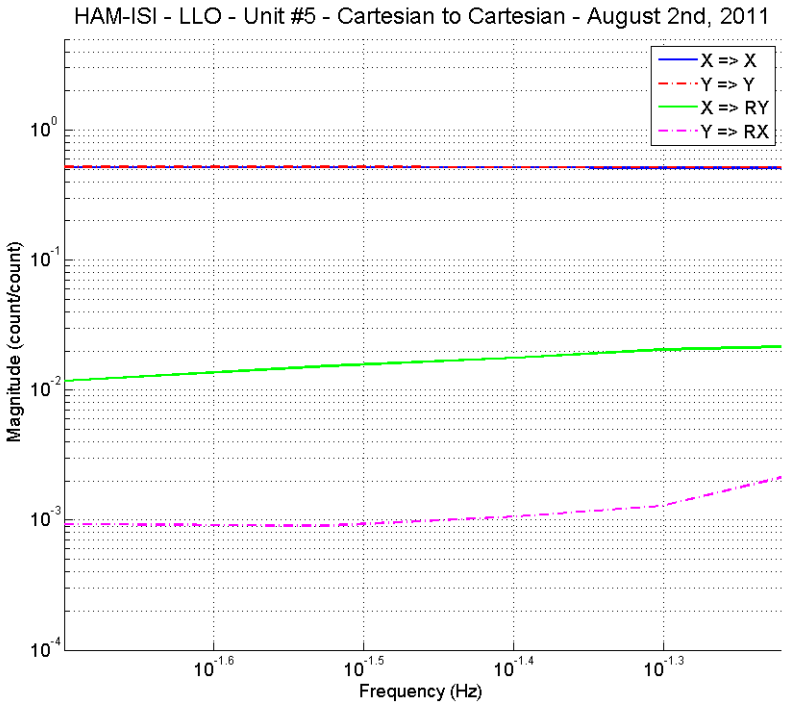


Figure - Lower Zero moment plane – Main and cross couplings at low frequency

Issues/difficulties/comments regarding this test

This test fails by a factor 5! We looked at what the GS 13s signal during the same tests and they seemed to indicate comparable LZMP on the 2 axis's. We redid the LZMP measurement after having realigned all the vertical CPS, and we got a second set of results:



LZMP Offset X - mm
6.333
LZMP Offset Y - mm
0.45712

We can see that realigning the CPS (improving their parallelism) helped quite a bit to improve the results but the X offset is still three time bigger than the criteria. We think that we might have an issue with the CPS or the horizontal actuators. This Unit will be retested as soon as possible.

Acceptance criteria:

- X offset must be less than 2 mm
- Y offset must be less than 2 mm

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

- ***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***

Scripts files for processing and plotting in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Transfer_Functions/Simulation/Damping

- HAM_ISI_LLO_Unit_5_Damping_TF_2011_08_02.m

Figures in SVN at:
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Figures/Transfer_Functions/Simulations/Damping/

- LLO_HAM_ISI_Unit_5_Damping_TF Horizontals_2011_08_02.fig
- LLO_HAM_ISI_Unit_5_Damping_TF Verticals_2011_08_02.fig

Results are saved in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Transfer_Functions/Simulations/Damping/

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

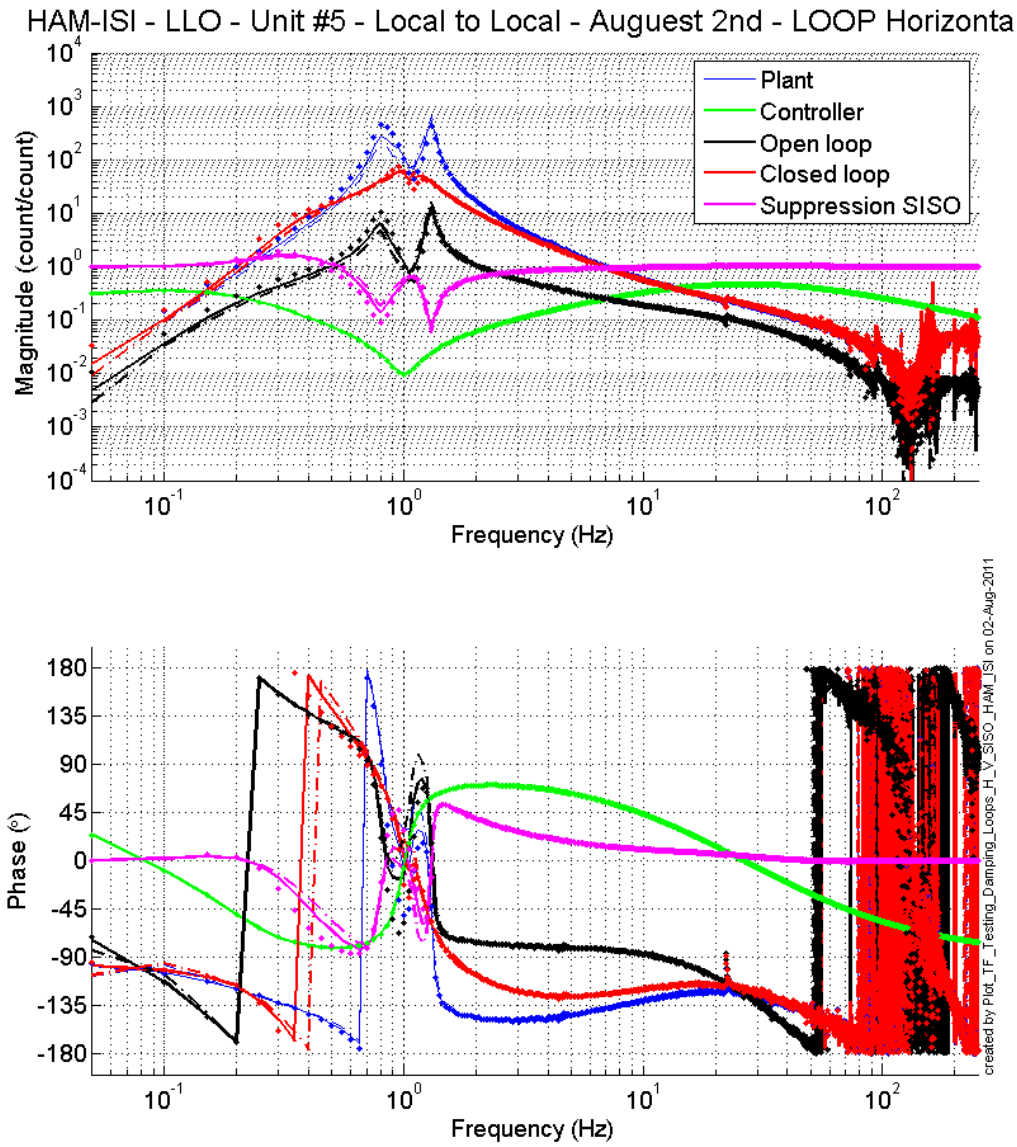


Figure - Horizontal damping loops - Simulation

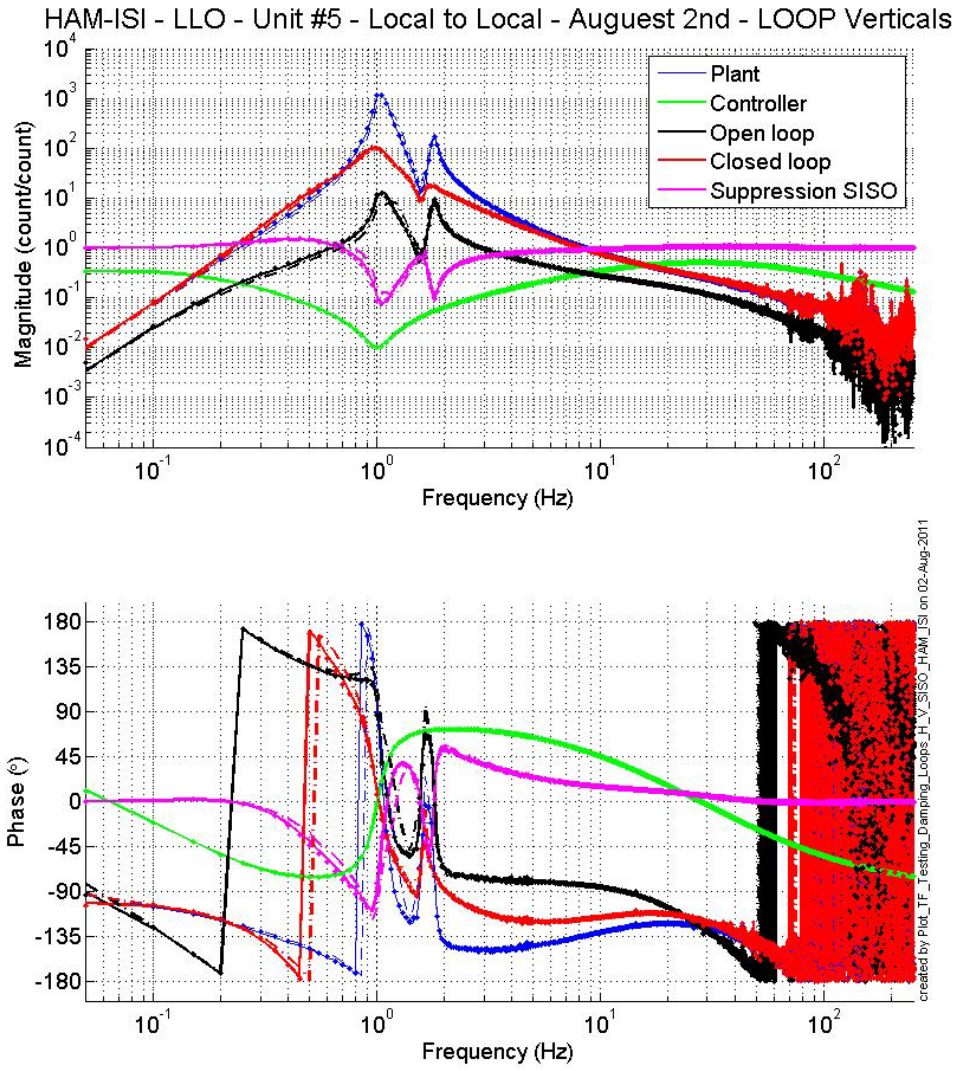


Figure - Vertical damping loops - Simulation

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: ___**

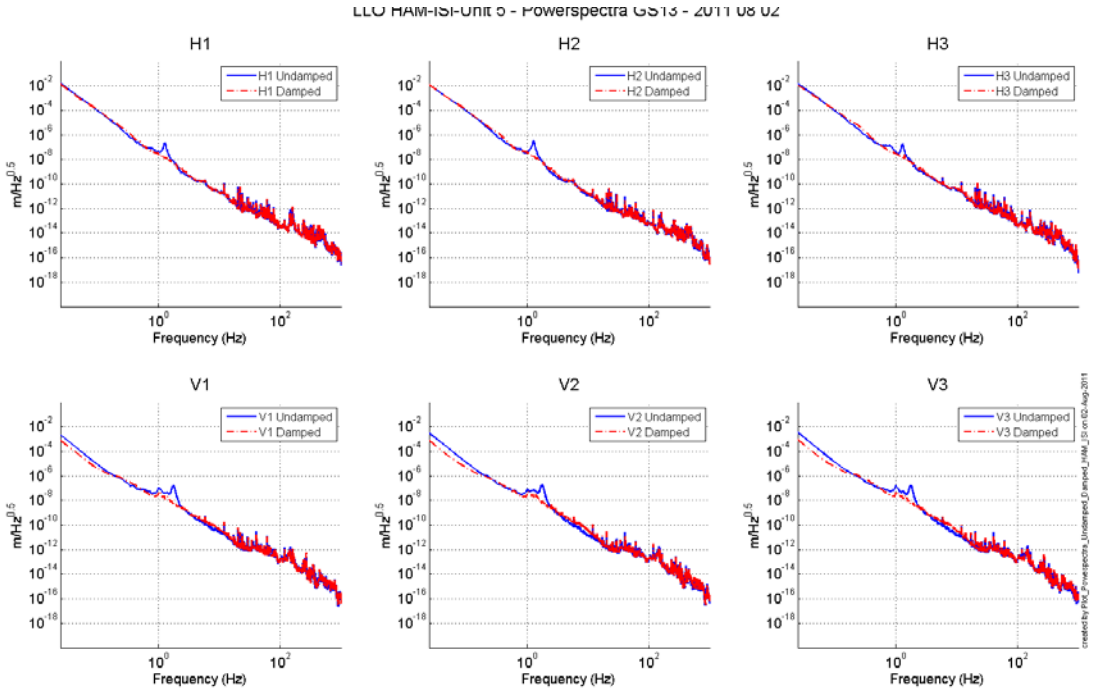
- ***Step 19.2 - Powerspectra – Experimental***

Data files in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_5/Powerspectra/Damping/

Scripts files for taking data and plotting in SVN at:
/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Scripts/Data_Collection/

- Powerspectra_Measurements_Undamped_Damped_HAM_ISI.m

Figures in SVN at:
/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_4/Figures/Powerspectra/Damping/
- LLO_HAM_ISI_Unit_5_Calibrated_PSD_CPS_Undamped_Damped_2011_08_02.fig
- LLO_HAM_Unit_5_Suppression_Exp_vs_Sim_2011_08_04.fig



Sensitivity:
The figure below compare the sensitivity ('Undamped/Damped') of LLO HAM (Aug 2008) and LHO Unit 2. Performances are very similar, which confirms that we can use the damping loop as they are (modulo electronics change compensation). The plot also shows that the measured performance matches with the prediction.

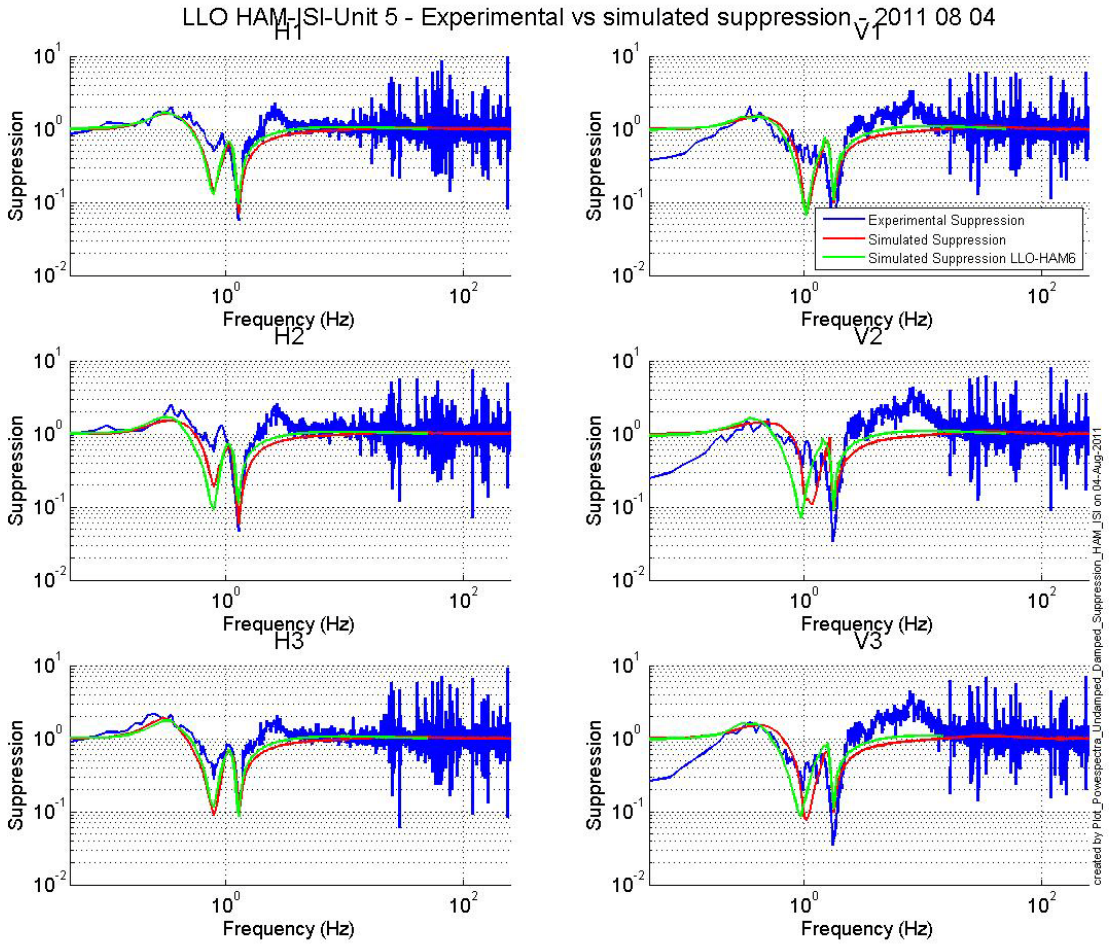


Figure – Horizontal (left) and vertical (right) damping loops - Experimental

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: ___**

Conclusion

A few issues were found during the testing of this unit 5. They are summed up here:

1. Sensor gaps not recorded on the jig
2. Measure of the sensors gaps not done
3. CPS 12068 & 12061 have an Amplitude Spectral Density too high at 0.1Hz
4. Stage 0 was not fully level, probably due to the stand (different from the one used for the other unit)
5. Position sensor Unlocked/Locked Powerspectra is slightly too high at low frequencies
6. Could not check pressure on V1 & V3 GS-13.
7. The X Offset on the LZMP is three times bigger than the acceptance criteria.

Only item 7 motivated our decision to re-test that unit. We will use the same test stand used for the previous units, and investigate whether the capacitive position sensors, or the actuators may be responsible for the issue.