

LIGO Laboratory / LIGO Scientific Collaboration

LIGO- E1000327

LIGO

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**aLIGO HAM-ISI, Pre integration Test report, Phase 1,
LLO Unit #3**

E1000327 – V4

Joe Hanson, Adrien Le Roux, Michael Vargas, Céline Ramet, Vincent Lhuillier

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Advanced LIGO Project

This is an internal working note
of the LIGO Laboratory

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

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

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

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

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Introduction

This document presents the tests performed to characterize and validate the “HAM-ISI LLO Unit #3”. This unit is the 3rd unit assembled for aLIGO at LLO.

The procedure document used to perform this test is:

- E1000309 -V5 - 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(m m)	Location on the Jig	Gap Standoff on Jig(mm/in)	Voltage before zeroing	Voltage after zeroing. Prebake	Voltage after zeroing. Post bake
12057	NR	NR	NR	NR	NR	NR	NR
12026	NR	NR	NR	NR	NR	NR	NR
12013	NR	NR	NR	NR	NR	NR	NR
12059	NR	NR	NR	NR	NR	NR	NR
12056	NR	NR	NR	NR	NR	NR	NR
12083	NR	NR	NR	NR	NR	NR	NR

NR: not recorded

Will be measured for the next units.

Sensors noise spectra measured before baking:

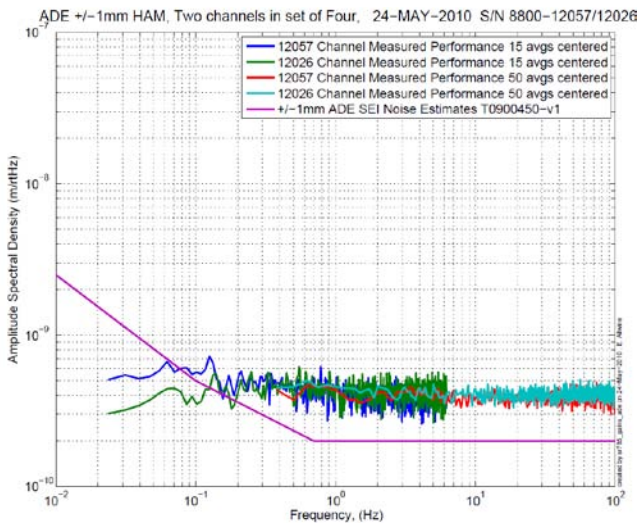


Figure - H1 and V1 sensor noise

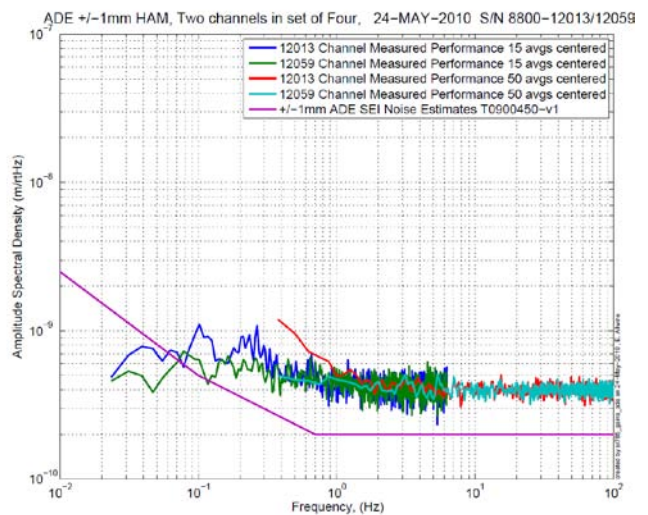


Figure - H2 and V2 sensor noise

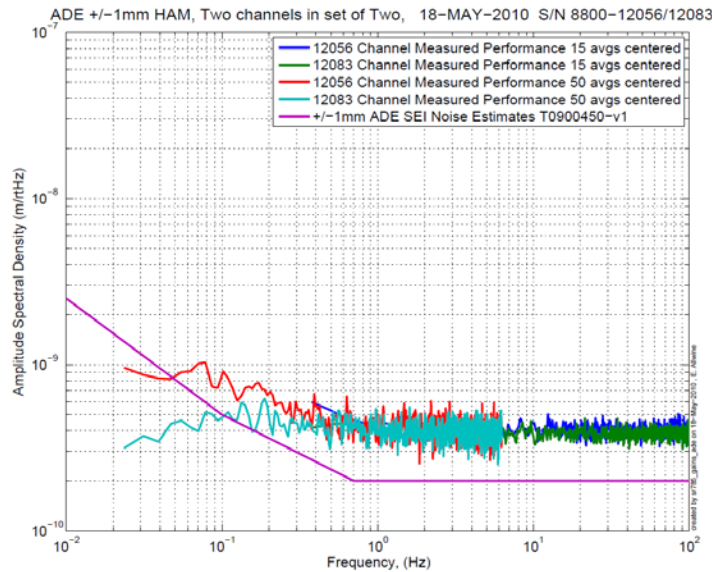


Figure - H3 and V3 sensor noise

Acceptance Criteria:

- Power spectrum magnitudes must be lower than:
 - o 9.e-10 m/ $\sqrt{\text{Hz}}$ at 0.1Hz
 - o 6.e-10 m/ $\sqrt{\text{Hz}}$ at 1Hz

Issues/difficulties/comments regarding this test: Values of sensor gaps and zeroing were not recorded. Waived for this unit.

12013 (used for H2) is noisier than other sensors, still passes.

Test result:

Passed: X

Failed:

▪ **Step 2: GS13**

All the data related to GS-13 post podding testing can be found in the SVN at :

SeismicSVN\seismic\Common\Data\aLIGO_GS13_TestData\PostMod_TestResults_PDFs.

E100058 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

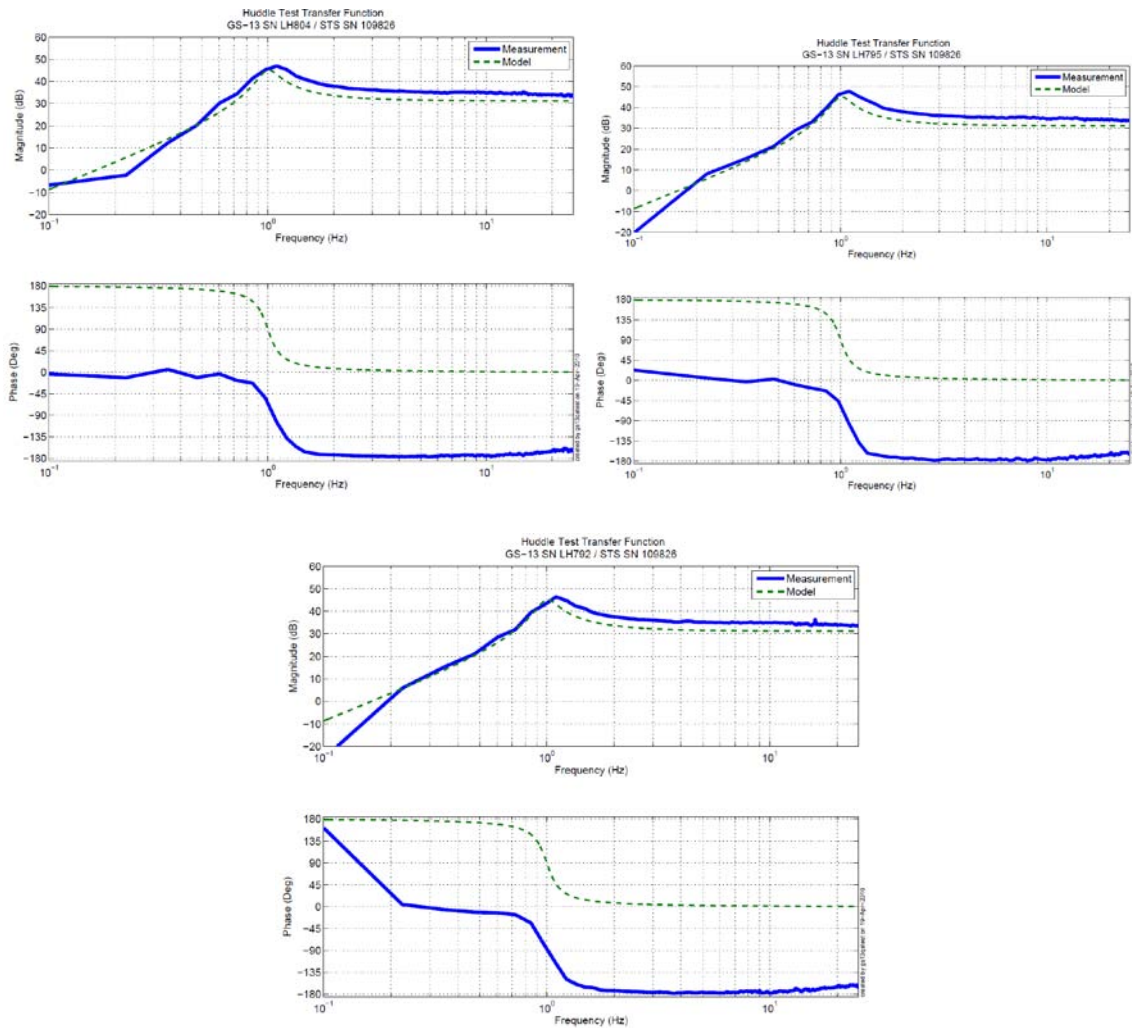


Figure - Huddle testing of Horiz GS-13 804,795, and 792 after aLIGO modifications

○ Step 2.2 – Vertical GS-13s

Huddle testing

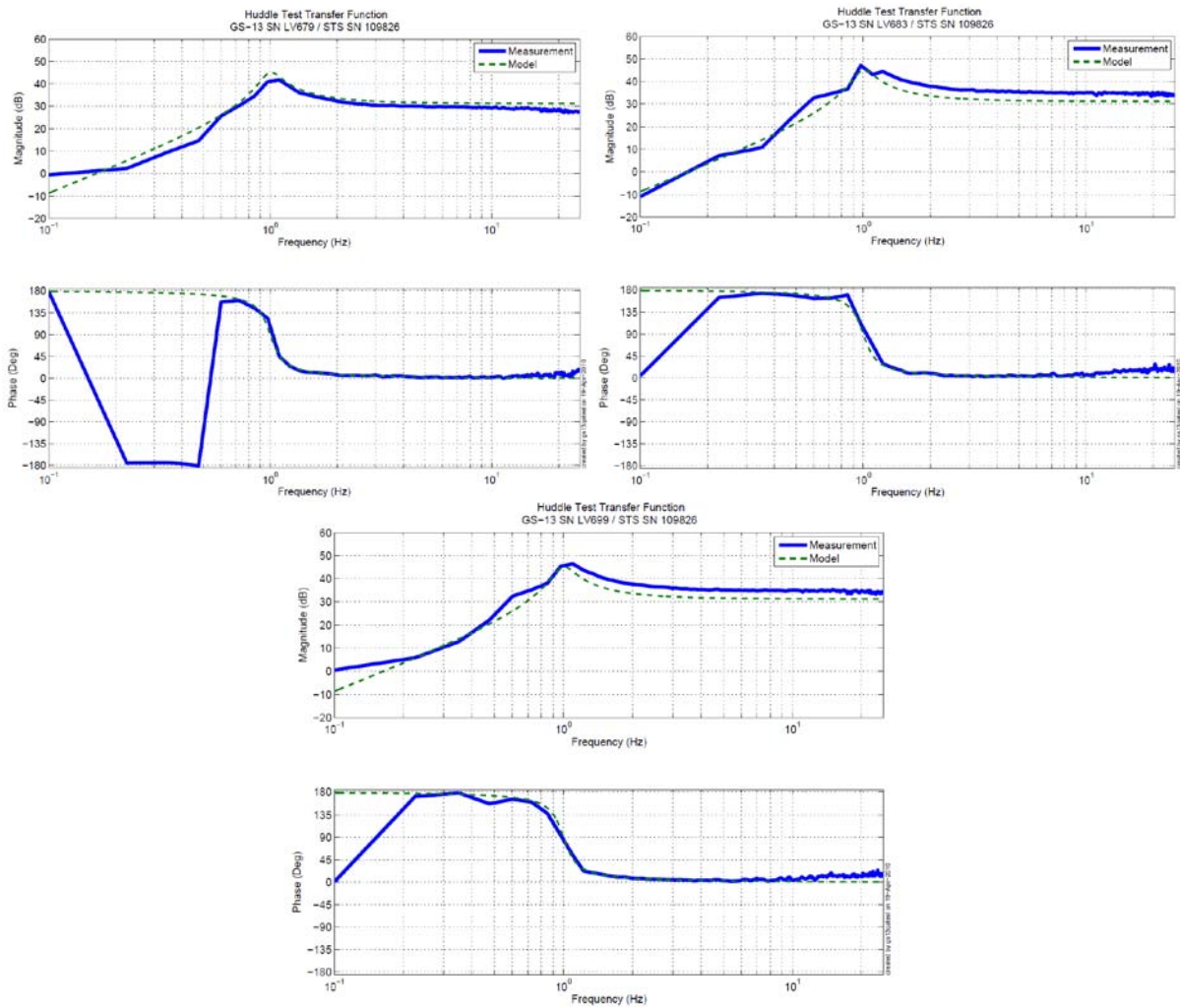


Figure - Huddle testing of Vert GS-13 679,683 and 699 after aLIGO modifications

Driven testing

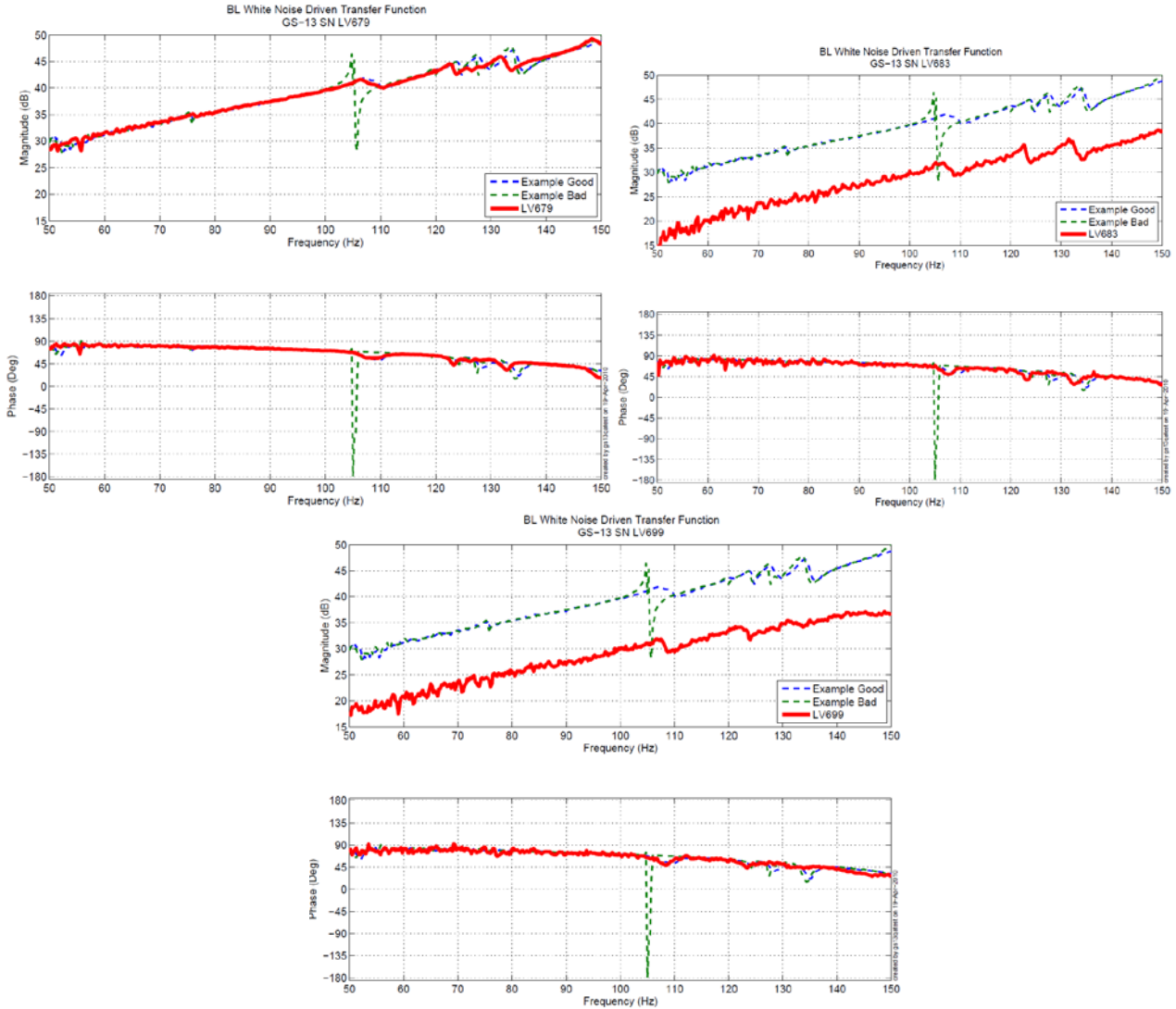


Figure - Driven Transfer Function of Vert GS-13 679,683 and 699 after aLIGO modifications

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.

<p>Actuator Serial #: L087 Operator Name: Gordon, Matt Date: 11/22/2009 Time: 11:48 AM Actuator Coil Resistance: 6.28 Ohms, PASS Ambient Temperature: 71.1 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.526 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.508</p>	<p>Actuator Serial #: L088 Operator Name: Gordon, Matt Date: 11/21/2009 Time: 4:48 PM Actuator Coil Resistance: 6.31 Ohms, PASS Ambient Temperature: 70.0 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.530 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.506</p>
<p>Actuator Serial #: L096 Operator Name: Gordon, Matt Date: 11/23/2009 Time: 3:50 PM Actuator Coil Resistance: 6.26 Ohms, PASS Ambient Temperature: 71.1 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.530 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.509</p>	<p>Actuator Serial #: L134 Operator Name: Gordon, Matt Date: 4/12/2010 Time: 3:25 PM Actuator Coil Resistance: 6.34 Ohms, PASS Ambient Temperature: 73.3 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.536 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.506</p>
<p>Actuator Serial #: L137 Operator Name: Gordon, Matt Date: 4/12/2010 Time: 4:19 PM Actuator Coil Resistance: 6.42 Ohms, PASS Ambient Temperature: 73.3 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.530 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.501</p>	<p>Actuator Serial #: L145 Operator Name: Gordon, Matt Date: 4/13/2010 Time: 11:44 AM Actuator Coil Resistance: 6.45 Ohms, PASS Ambient Temperature: 73.1 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.526 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.506</p>

Table 1 Extract of T0900564-testing at Qinetiq

Acceptance Criteria:

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

Test result:

Passed: X

Failed: ___

II. Tests to be performed during assembly

- *Step 1: Check torques on all bolts*

Acceptance Criteria:

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

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

- *Step 2: Check gaps under Support Posts*

Acceptance Criteria:

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

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

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

Acceptance Criteria:

- Shim inserted won't pass between parts.

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

- *Step 4: Blade spring profile*

Blade #	Base (")	Tip (")	Flatness (mils)
1	.495	.491	+4
2	.501	.489	+12
3	.498	.490	+8

Table 2 - Blade profile

Acceptance Criteria

- Blades must be flat within 0.020" inches.

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

Issues/difficulties/comments regarding this test:
 Passed on first try. No adjustment necessary.

▪ **Step 5: Gap checks on actuators**

Actuator	Front Gap (1/1000")	Back Gap (1/1000")
V1	80	90
V2	90	75
V3	95/85	65/80
H1	85	
H2	80	
H3	80	

Acceptance Criteria

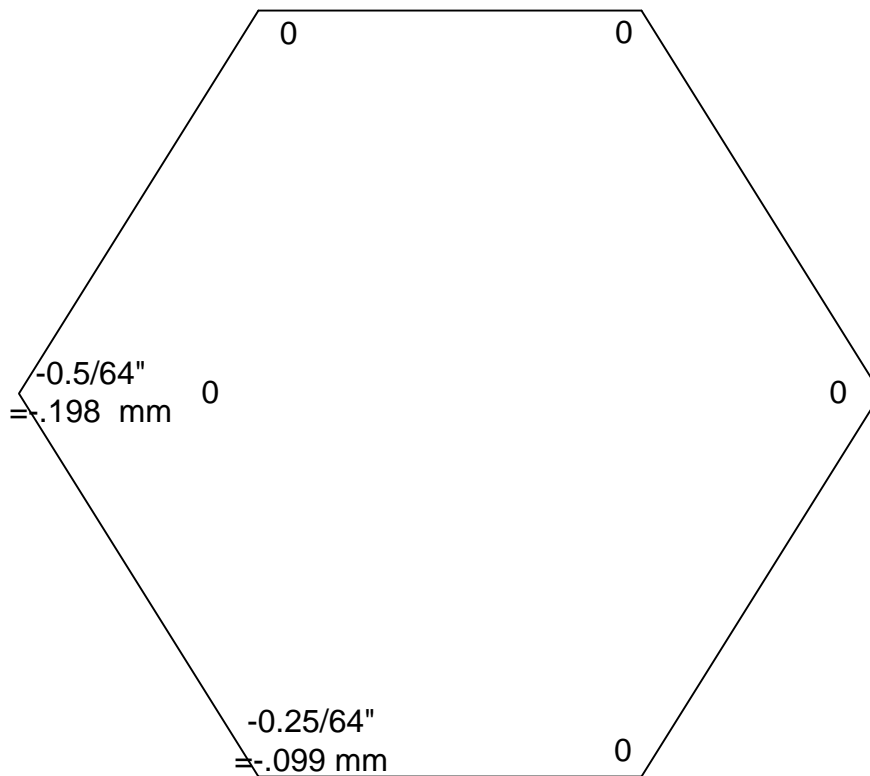
- Gaps must be within 0.010" of design (i.e. 0.090" and .070" pass, but 0.095" and 0.065" doesn't).

Test result:

Passed:

Failed: X

▪ **Step 6: Check level of Stage 1 optical table**





Max angle= $(.5/64)/85.59= 91$ urad

Acceptance Criteria 100 urad.

Test result:

Passed: X

Failed:

▪ *Step 7: Mass budget*

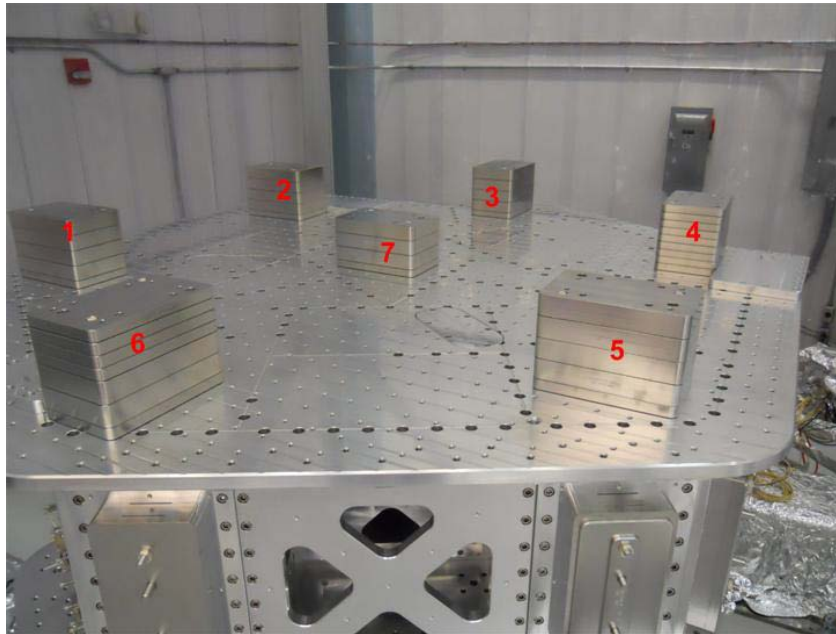


Figure - Optical table masses distribution

	Mass (kg)
t1	45.00
t2	45.00
t3	45.00
t4	45.00
t5	45.00
t6	45.00
t7	35.00
total	305.00

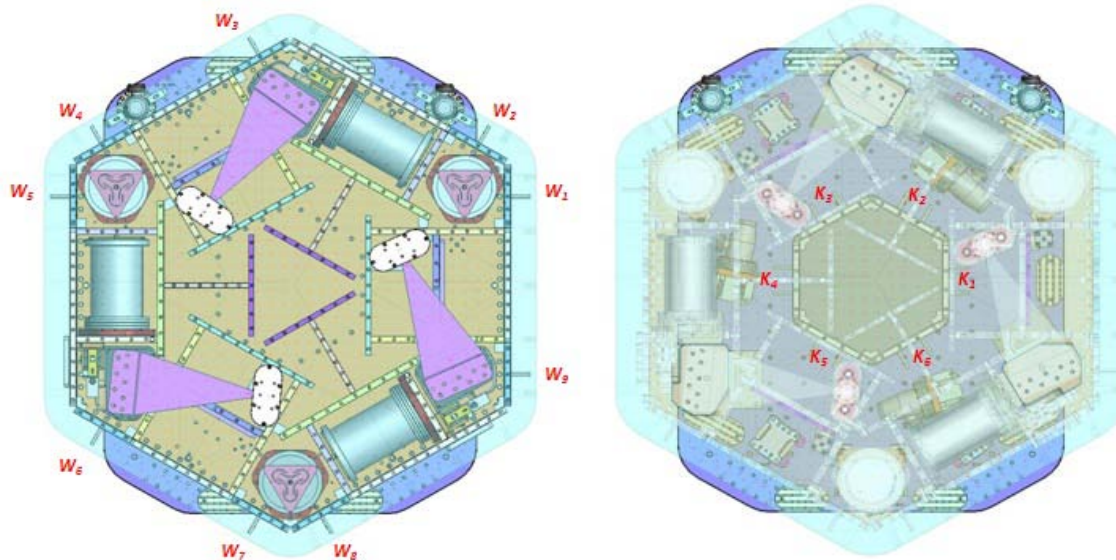


Figure – Keel Masses and Wall masses location

	00	01	02	03	04	05	06			
	0.6	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs	
w9							1	1	42.8	19.41
w1	1						1	1	43.4	19.69
w2							1	1	42.8	19.41
w3							1	1	42.8	19.41
w4			1		1		1	1	48.4	21.95
w5			1				1	1	43.9	19.91
w6	2						1	1	44	19.96
w7							1	1	42.8	19.41
w8							1	1	42.8	19.41
Side Masses										
Total	3	2	0	1	0	9	9	393.7		178.58

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

Lockers	Shim thickness (mil)
A	125
B	125
C	125
D	125

Table – Shims Thickness

	Side	Keel	Top	Total
Weigh (kg)	178.58	90.08	305.00	573.66

Table - Masses distribution

Acceptance Criteria

The Mass budget must be

- 596.7Kg +/-25Kg (4%)

Test result:

Passed: X

Failed:

▪ *Step 8: Lockers adjustment*

D.I at Lockers	Dial indicators V	Dial indicators H
A	0.5	-1
B	2	0
C	.25	0
D	-1.5	-1.5

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

Issues/difficulties encountered during this test :

Acceptance Criteria

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

Test result:

Passed: X

Failed:

III. Tests to be performed after assembly

- *Step 1 - Actuators Inventory*

Actuator	Actuator S/N
H1	L 145
H2	L 088
H3	L 134
V1	L 096
V2	L 137
V3	L 087

Table - Actuators' inventory

Issues/difficulties/comments regarding this test:

Test result:

Passed: X

Failed: ___

- *Step 2 - Sensors Inventory*

Sensor	CPS S/N	ADE board serial #
H1	12057	
H2	12013	
H3	12056	
V1	12026	
V2	12059	
V3	12083	

Table - Capacitive position sensors' inventory

Geophones GS13	Serial Number	POD
H1	792/809	66/46
H2	804	26
H3	795	92
V1	699	56
V2	679	2
V3	683	60

Table - Geophones' inventory (cf E1000058)

Issues/difficulties/comments regarding this test:

Vertical GS-13 are staying on this unit, whereas horizontals are gotten off to test Unit #2

Test result:

Passed: X

Failed: ___

▪ *Step 3 - Electronics Inventory*

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

Hardware	Ligo reference	S/N
Coil driver	D0902744	S1000317
		S1000316
Anti Image filter	D070081	S1000251
Anti aliasing filter	D1000269	S1000244
		S1000245
Interface chassis	D1000067	S1000311
		S1000312
		S1000314

Table - Inventory electronics

Issues/difficulties/comments regarding this test:

We had to change one Anti aliasing filter prior to start testing on this unit.

Test result:

Passed: X

Failed:

▪ *Step 4 - Set up sensors gap*

10 Kg masses at each
corners

No mass

Table locked	ADE boxes on		ADE boxes on	
	Offset (Mean)	Std deviation	Offset (Mean)	Std deviation
Sensors				
H1	-36.967	1.2	-109.44	1.5
H2	254.8	1.1	243.71	0.8
H3	-23.343	0.7	-91.761	1.1
V1	-264.62	0.6	-52.461	1.6
V2	-148.73	1.8	24.719	1.5
V3	196.35	1.4	296.66	1.2

Table - Set-up sensors gap

Issues/difficulties/comments regarding this test: HAM-ISI – LLO unit#3 uses synchronized satellite boxes

Acceptance criteria:

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

Test result:

Passed: X

Failed:

▪ *Step 5 - Measure the Sensor gap*

Sensors	Gap measured on the Jig	Gap measured on the table
H1	NR	0.080"
H2	NR	0.085"
H3	NR	0.085"
V1	NR	0.085"
V2	NR	0.085"
V3	NR	0.085"

Table - Sensors gap

Issues/difficulties/comments regarding this test: No information of gaps measured on the Jig. Difficult to measure without scratching the target.

Acceptance criteria:

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

Test result:

Passed: X **Failed:**

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

Sensors	Table locked		Table unlocked	
	Offset (Mean)	Std deviation	Offset (Mean)	Difference
H1	-274.44	0.83234	664.2	938.64
H2	-43.197	0.75333	-327.25	-284.053
H3	159.76	0.74358	-561.14	-720.9
V1	-296.64	1.0669	583.93	880.57
V2	245.48	1.4453	495.1	249.62
V3	-362.15	1.627	-1144.2	-782.05

Table – Sensor gaps after platform release

Issues/difficulties/comments regarding this test:

Acceptance criteria:

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

Test result:

Passed: X **Failed:**

- **Step 7 - Check range of motion (hand pushing)**
 - **Step 7.1 – Test N°1**

	CPS read out		Calculated after calibration	
Sensors	UP (Counts)	Down (Counts)	UP (mil)	Down (mil)
V1	20269	-20331	24.0	-24.1
V2	20234	-20363	23.9	-24.1
V3	19885	-19746	23.5	-23.4
	CPS read out		Calculated after calibration	
Sensors	CW(-RZ)	CCW (+RZ)	CW (mil)	CCW (mil)
H1	18281	-22331	21.6	-26.4
H2	24413	-19937	28.9	-23.6
H3	18099	-22126	21.4	-26.2

Table - Optic table range of motion

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

- **Step 7.2 – Test N°2**

Displacement sensors and actuator gap check:

	Push in positive direction	Push in negative direction	Railing	Actuator Gap Check
H1	20691	-26431		X
H2	24701	-24100		X
H3	25028	-22929		X
V1	19785	-20422		X
V2	31629	-32519		X
V3	19762	-21787		X

Table - Sensor and Actuator gap check

Acceptance criteria:

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

Test result: Passed: X Failed: ___ .

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

Data files in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Powerspectra/Undamped
 - LLO_HAM_ISI_Unit_3_Calibrated_PSD_CPS_GS13_Unlocked_Locked_2011-03-25.mat

Scripts files for processing and plotting in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Powerspectra/Undamped
 - Powerspectra_Measurement_HAM_ISI_Locked_Unlocked.m

Figures in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Figures/Powerspectra/Undamped
 LLO_HAM_Unit_3_Calibrated_PSD_CPS_Unlocked_Locked_2011-03-25.pdf

CPS calibration:

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

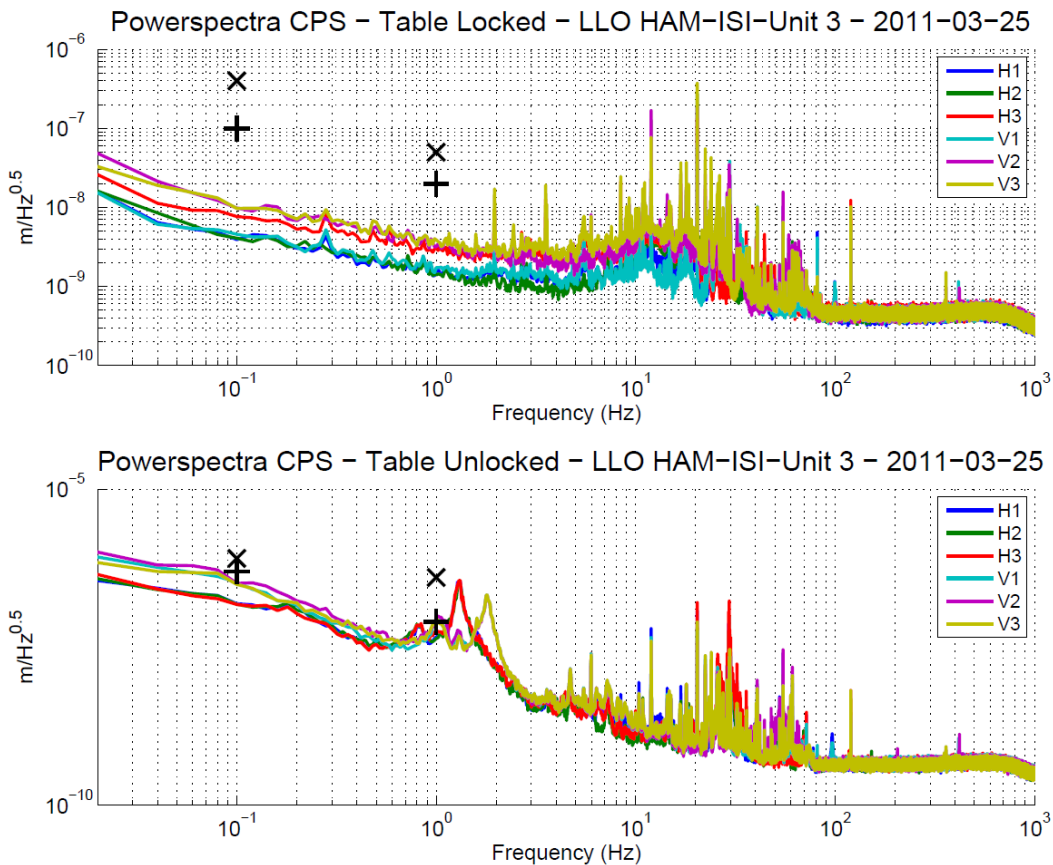


Figure - Calibrated CPS power spectrum
 (+ signs are Horizontal requirements, x signs are Vertical requirements)

Acceptance criteria:

- No cross talk (peaks at low frequencies + harmonics on measurements)
- Magnitude of power spectrums must be lower than

	Locked		Unlocked	
	at 0.1Hz	at 1Hz	at 0.1Hz	at 1Hz
Horizontal	1.00E-07	2.00E-08	5.00E-07	8.00E-08
Vertical	4.00E-07	5.00E-08	8.00E-07	4.00E-07

Test result: Passed: X Failed:

- **Step 9 - GS13 power spectrums**
 - **Step 9.1 - Table locked and unlocked (free)**

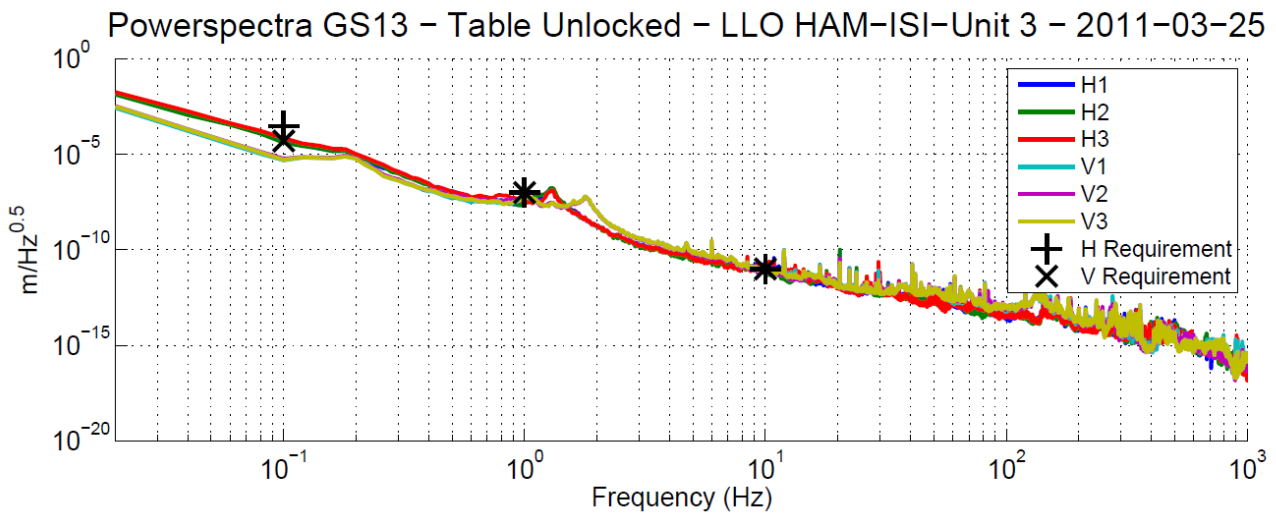
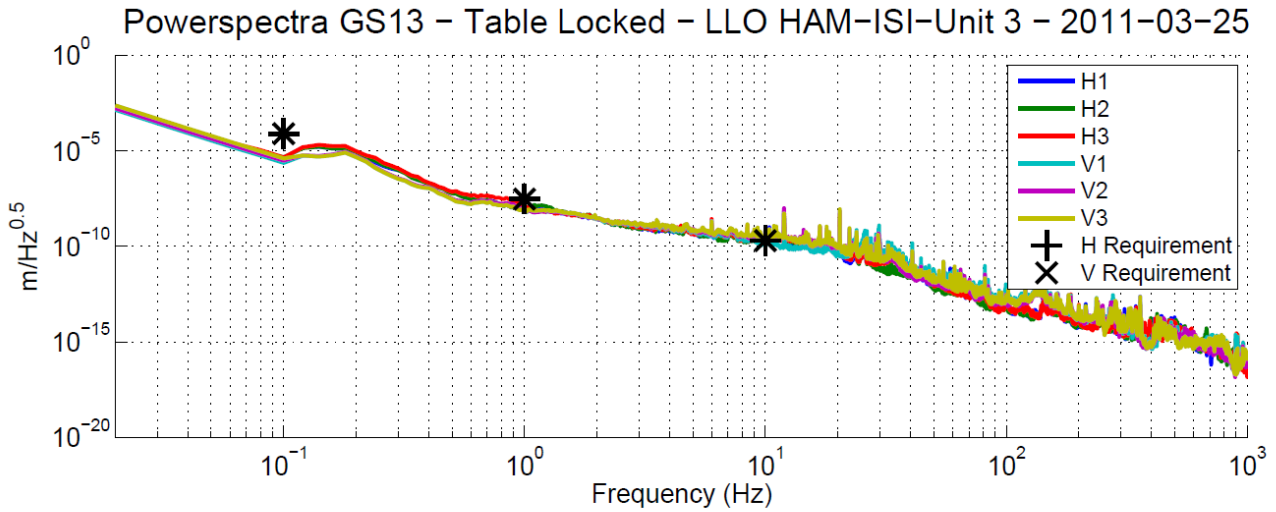


Figure – Power spectrum Calibrated GS13

○ *Step 9.2 – 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.

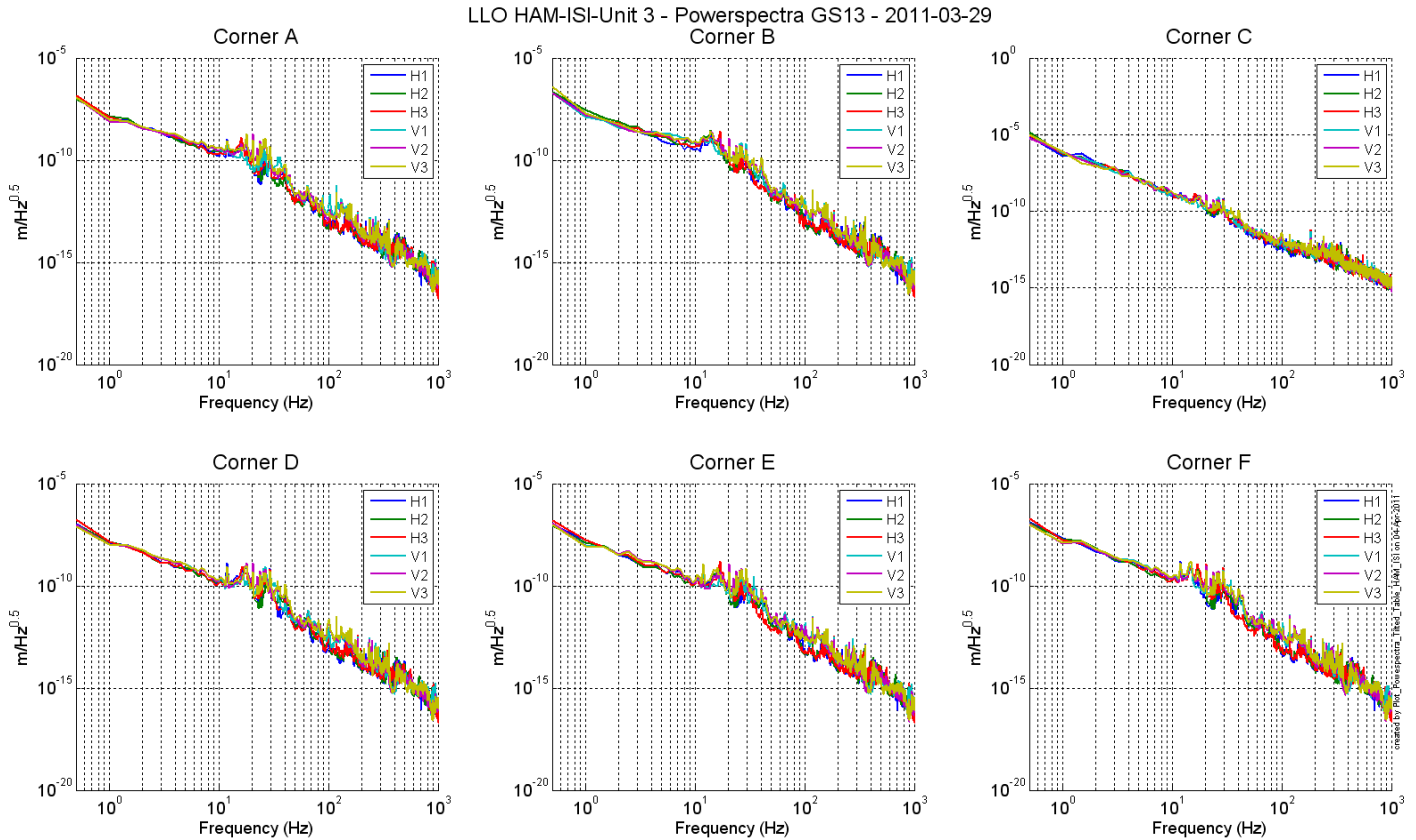


Figure – Power spectrum Calibrated GS13 with mass at corner

Data files in SVN at:

- /opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/ Powerspectra/Undamped
- LLO_HAM_ISI_Unit_3_Calibrated_PSD_CPS_GS13_Unlocked_Locked_2011-03-25.mat
- LLO_HAM_ISI_Unit_3_Calibrated_PSD_GS13_Table_Tilted_2011-03-29.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/Old_Scripts
- Powerspectra_Measurement_HAM_ISI_Locked_Unlocked.m
- /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_3/Figures/ Powerspectra/Undamped
- LLO_HAM_Unit_3_Calibrated_PSD_GS13_Unlocked_Locked_2011-03-25.pdf
- LLO_HAM_ISI_Unit_3_Calibrated_PSD_GS13_Table_Tilted_2011-03-29.pdf

Acceptance criteria:

- With table locked, magnitudes of power spectra must be lower than:

	Table locked		
	at 0.1Hz	at 1Hz	at 10Hz
H & V Geophones	8.E-05	3.E-08	2.E-10

- With table unlocked, magnitudes of power spectra must be lower than:

	Table unlocked		
	at 0.1Hz	at 1Hz	at 10Hz
Horizontal Geophones	3.E-04	1.E-07	1.E-11
Vertical Geophones	5.E-05	1.E-07	1.E-11

- With table unlocked and tilted, magnitudes of power spectra must be lower than:

	Table unlocked (tilted with masses)		
	at 0.1Hz	at 1Hz	at 10Hz
H & V Geophones	8.E-05	3.E-08	2.E-10

Test result:

Passed: X

Failed: _

▪ **Step 10 - 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
	6.3	O.L (infinity)	6.5	O.L (infinity)	6.4	O.L (infinity)
MEDM offset (1000 counts)	Measurement P2 (-) ; P1&P3 (+)		Measurement P2 (-) ; P1&P3 (+)		Measurement P2 (-) ; P1&P3 (+)	
	0.3		0.303		0.3	

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
	6.4	O.L (infinity)	6.4	O.L (infinity)	6.3	O.L (infinity)
MEDM offset (1000 counts)	Measurement P2 (-) ; P1&P3 (+)		Measurement P2 (-) ; P1&P3 (+)		Measurement P2 (-) ; P1&P3 (+)	
	0.303		0.296		0.298	

Table - Actuators resistance check

Issues/difficulties/comments regarding this test:

Acceptance criteria:

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

Test result:

Passed: X

Failed:

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

○ **Step 11.1 - Actuators sign**

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

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

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

	Positive and negative offset Drive(+/-30000 counts)					
	V1	V2	V3	H1	H2	H3
V1 readout (counts)	-24840			X	X	X
	23704					
V2 readout (counts)		-23504		X	X	X
		24473				
V3 readout (counts)			-25079	X	X	X
			24232			
H1 readout (counts)	X	X	X	-19988		
				19535		
H2 readout (counts)	X	X	X		-25296	
					27191	
H3 readout (counts)	X	X	X			-22424
						21599

Table - Range of motion - Local drive

Data files in SVN at:

- /opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Static_Tests
- LLO_HAM-ISI_Unit_3_Range_Of_Motion_20110329.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

Issues/difficulties/comments regarding this test:

Acceptance criteria:

- Main couplings read out must be at least +/-16000 counts (~0.020")
- Signs of actuators drive and sensors read out have to be the same

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

▪ *Step 12 - Vertical Sensor Calibration*

Lockers	D.I readout for a negative drive	D.I readout without any drive	D.I readout for positive drive	
A	19	0	-19	
B	19.25	0	-19	
C	18.5	0	-19	
D	19	0	-19	
Average	18.9375	0	-19	-37.9
Sensors	Counts	Counts	Counts	Difference (Counts)
V1	-15407	703	16730	-32137
V2	-15595	551	16437	-32032
V3	-17675	-1772	14357	-32032
			Average	-32067

Table - Calibration of capacitive position sensors

Vertical sensitivity: $32067/37.91 = 845.3$ count/mil

or 845.3 count/mil * $1/1638$ V/count = 0.516 V/mil

or 25400 nm/mil * $1/845.3$ mil/count = 30.05 nm/count

Difference with Nominal sensitivity = $(845.3-840)/840=-0.63\%$

Issues/difficulties/comments regarding this test:

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

Test result:

Passed: X

Failed:

▪ *Step 13 - Vertical Spring Constant*

Sensors	Mean diff counts	Mean diff m	K (N/m)
V1	7370	2.23E-04	8.81E+04
V2	7538	2.28E-04	8.62E+04
V3	8553	2.58E-04	7.60E+04
Average (N/m)			2.50E+05

Table - Vertical spring constant

The measured vertical stiffness is 2.503e5N/m. The nominal vertical spring constant is 2.428e5N/m. The measured error on the vertical stiffness is 3.10%.

Issues/difficulties/comments regarding this test:

Acceptance criteria:

- Spring constant is within +10% -1% of 2.428e5 N/m (HPD FEA Results).

Test result:

Passed: X

Failed: ___

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

		H1	H2	H3	V1	V2	V3
Actuators (1000 counts)	H1	1967.669	1210.834	1224.792	-3.392	12.744	-33.92
	H2	1207.9290	2017.293	1256.419	11.939	21.785	-21.05
	H3	1224.299	1259.544	2015.90	37.030	16.072	-30.849
	V1	201.7530	172.320	-313.735	1415.569	-43.636	-546.33
	V2	-276.287	261.940	230.952	-554.369	1437.609	-44.9600
	V3	159.632	-385.887	142.389	44.354	-612.036	1403.714

Table - Main and cross coupling

Data files in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Static_Tests
 - LLO_HAM_ISI_Unit_3_Sensor_Readout_Local_20110331.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
 - o Collocated sensors must be 1400 counts +/- 10%
- **Horizontal**
 For a +1000 count offset drive on horizontal actuators
 - o Collocated sensors must be 2000 counts +/- 10%
 - o Non-collocated horizontal sensors must be 1250 counts +/-10%

Test result:

Passed: X

Failed:

▪ *Step 15 - Linearity test*

	Slope	Offset	Average slope	Variation from average(%)
H1	2.077	127.6	2.0845	-0.37
H2	2.102	-763		0.83
H3	2.075	-711		-0.46
V1	1.498	-282	1.4872	0.74
V2	1.479	368.3		-0.53
V3	1.484	-1024		-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

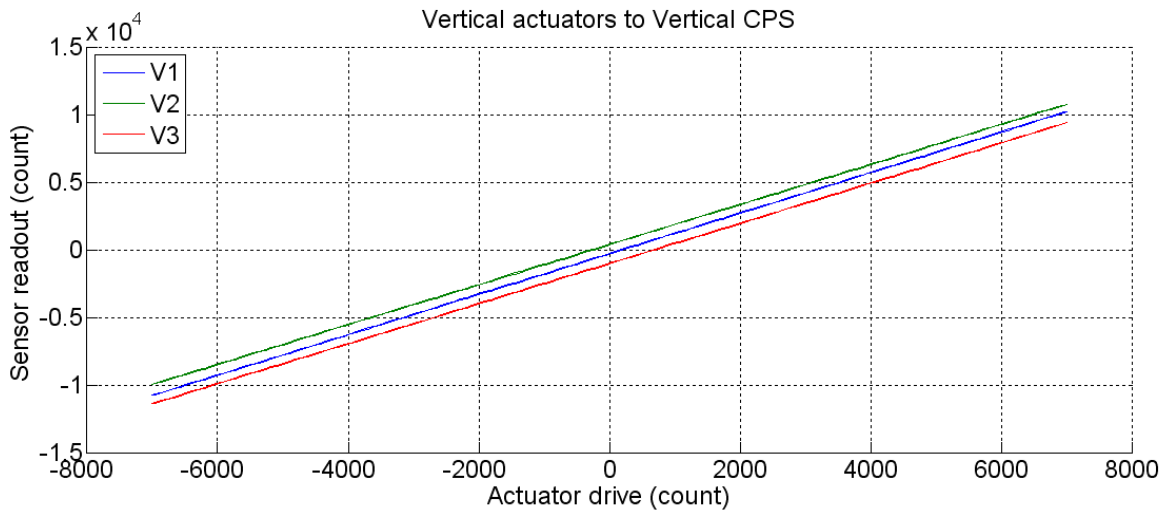
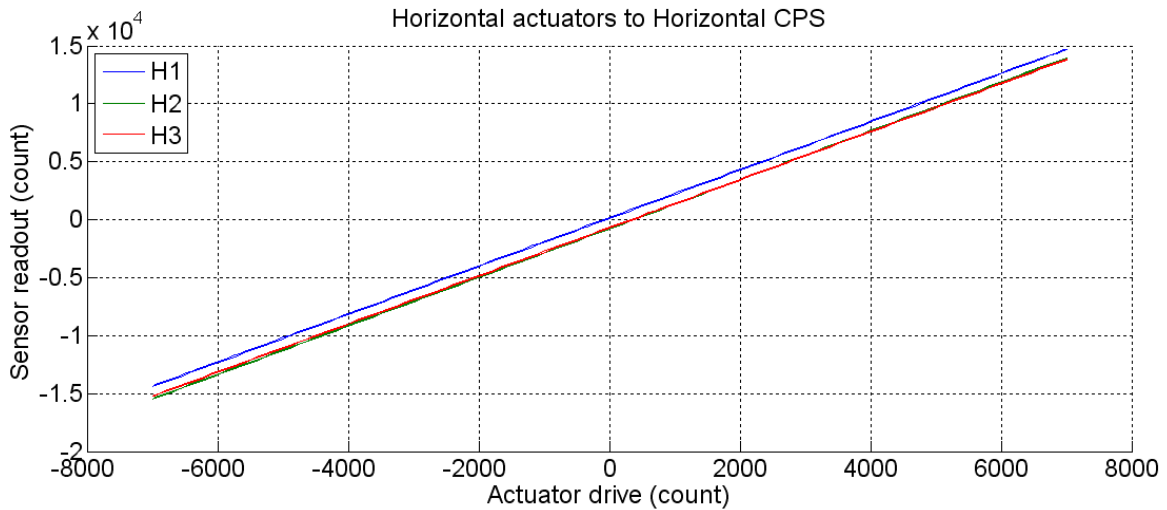


Figure - Horizontal and vertical actuators x HAM-ISI x sensors

Data files in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Linearity_test
- LLO_HAM_ISI_Unit_3_Linearity_test_20110407.mat

Figures in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Figures/Linearity_test
- LLO_HAM_ISI_Unit_3_Linearity_test_20110407.fig
LLO_HAM_ISI_Unit_3_Linearity_test_20110407.pdf

Issues/difficulties/comments regarding this test:

Acceptance criteria:

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

Test result:

Passed: X

Failed: ___

▪ **Step 16 – Static tests in the general coordinate basis**

1000 counts drive		X Drive	Y Drive	Z Drive	Rx Drive	Ry Drive	Rz Drive
Sensors readout (count)	H1	263.528	-390.4432	39.232	-351.599	-234.314	-1870.593
	H2	232.73	510.05	51.46	511.84	-214.09	-1926.44
	H3	-492.32	23.53	10.56	70.06	532.44	-1901.82
	V1	-5.871	6.292	248.899	-510.236	-1619.426	11.019
	V2	-21.28	-33.566	239.421	1633.514	398.43	-57.855
	V3	2.8	-18.2	270.36	-1169.8	1208.911	29.8
	Direction read out	492.38	524.71	256.965	2516.66	2506.73	2404.763

Table - Tests in the general coordinate basis

Issues/difficulties/comments regarding this test:

Acceptance criteria:

		X Drive	Y Drive	Z Drive	Rx Drive	Ry Drive	Rz Drive
Sensors readout (count)	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 17 - 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 17.1 - 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_3/Transfer_Functions/Measurements/Undamped/

- LLO_HAM_ISI_Unit_3_Data_TF_L2L_50mHz_500mHz_20110406-181629.mat
- LLO_HAM_ISI_Unit_3_Data_TF_L2L_500mHz_5Hz_20110406-151108.mat
- LLO_HAM_ISI_Unit_3_Data_TF_L2L_200Hz_800Hz_20110406-120426.mat
- LLO_HAM_ISI_Unit_3_Data_TF_L2L_5Hz_200Hz_20110406-133747.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_3/Transfer_Functions/Measurements/Undamped/

- Plot_LLO_HAM_ISI_Unit_3_TF_L2L_2011_04_06.m

Figures in SVN at:

opt/svncommon/seisvn/seismic/HAMISI/X2/Data/Unit_3/Figures/Transfer_Functions/Measurements/Undamped/

- LLO_HAM_ISI_Unit_3_TF_L2L_H_CPS_50mHz_800Hz_2011_04_06.fig
- LLO_HAM_ISI_Unit_3_TF_L2L_V_CPS_50mHz_800Hz_2011_04_06.fig
- LLO_HAM_ISI_Unit_3_TF_L2L_H_GS13_50mHz_800Hz_2011_04_06.fig
- LLO_HAM_ISI_Unit_3_TF_L2L_V_GS13_50mHz_800Hz_2011_04_06.fig

Storage of measured transfer functions in the SVN at:

opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Transfer_functions/Measurements/Undamped/

- LLO_HAM_ISI_Unit_3_Data_TF_L2L_2011_04_06.mat

The local to local transfer functions are presented below.

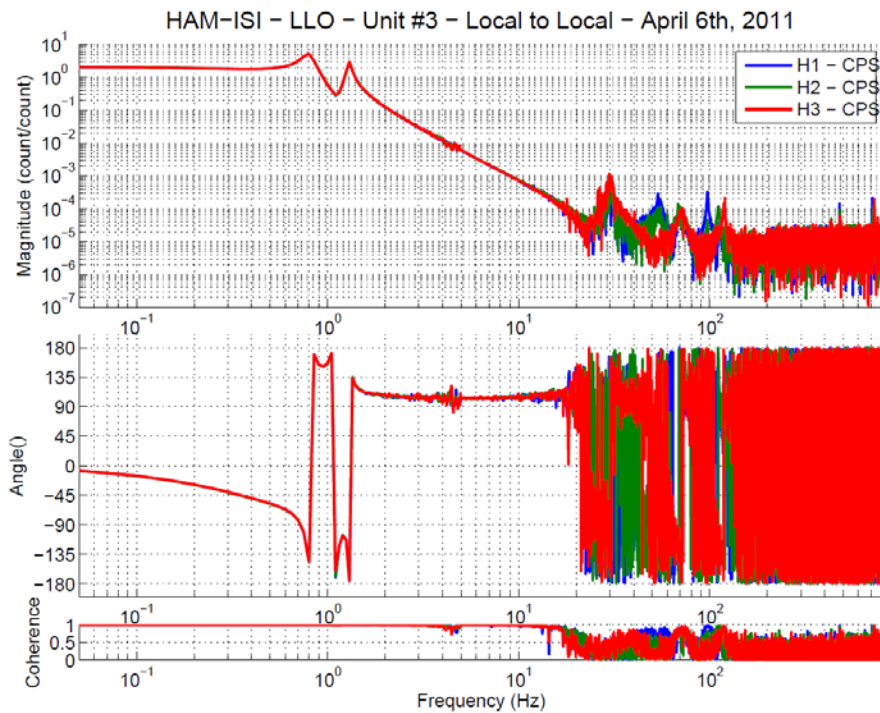


Figure - Local to Local Measurements – Horizontal capacitive sensors

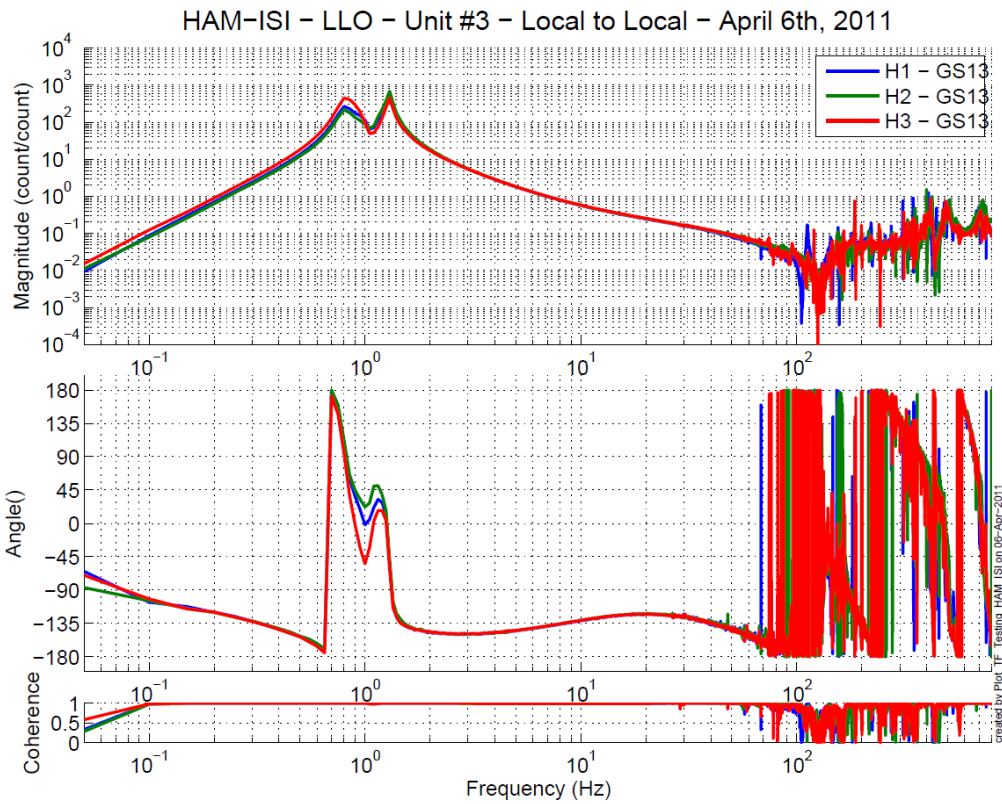


Figure - Local to Local Measurements – Horizontal inertial sensors

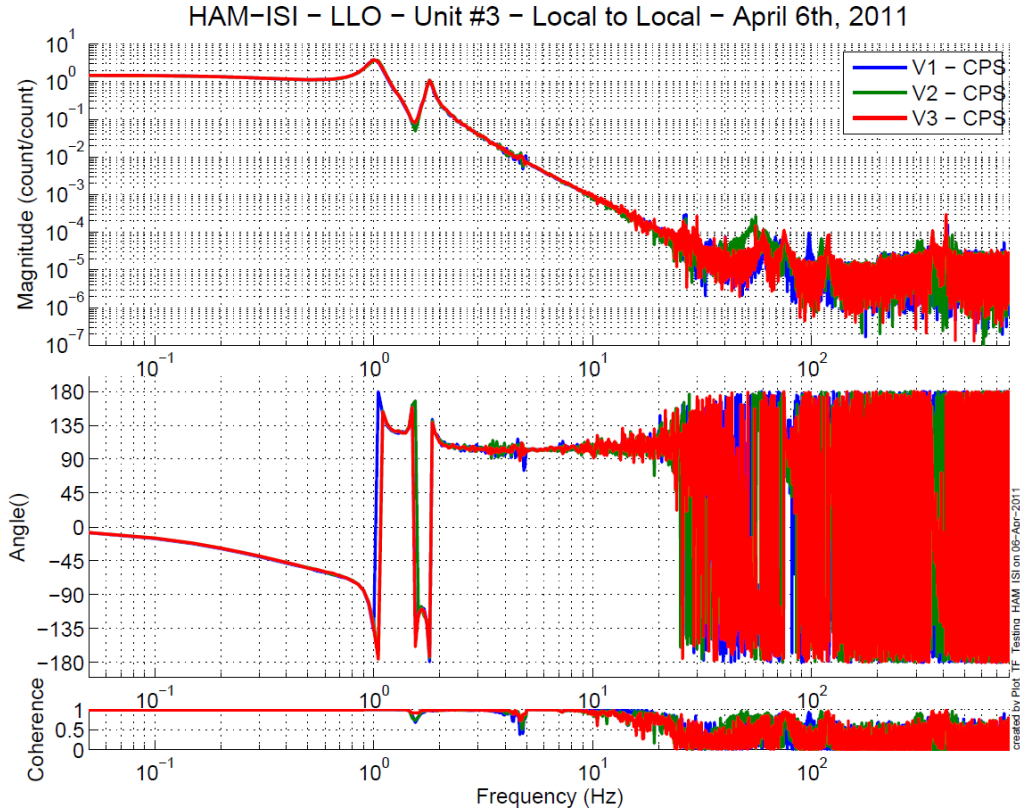


Figure - Local to Local Measurements – Vertical capacitive sensors

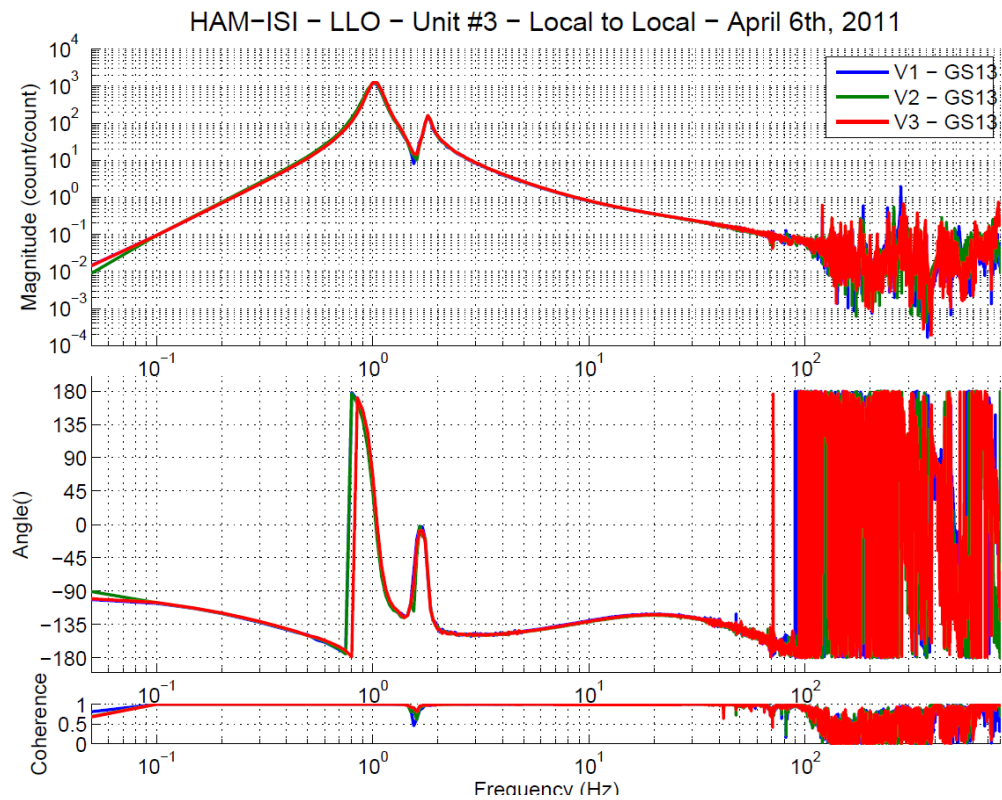


Figure - Local to Local Measurements – Vertical inertial sensors

Issues/difficulties/comments regarding this test:

Cables contacting Stage 1 and Stage 0 created issues in the .5 to 5 Hz.
 At low frequencies, the horizontal GS-13s present some differences.

o *Step 17.2 - 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_3/Transfer_Functions/Measurements/
 Undamped/

- LLO_HAM_ISI_Unit_3_Data_TF_C2C_50mHz_500mHz_20110405-215335.mat
- LLO_HAM_ISI_Unit_3_Data_TF_C2C_500mHz_5Hz_20110405-184814.mat
- LLO_HAM_ISI_Unit_3_Data_TF_C2C_5Hz_200Hz_20110405-171453.mat
- LLO_HAM_ISI_Unit_3_Data_TF_C2C_200Hz_800Hz_20110405-154132.mat

Scripts files for processing and plotting in SVN at:

opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Transfer_Functions/Measurements/
 Undamped/

- Plot_LLO_HAM_ISI_Unit_3_TF_C2C_2011_04_06.m

Figures in SVN at:

opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Figures/Transfer_Functions/
 Measurements/Undamped/

- LLO_HAM_ISI_Unit_3_TF_C2C_X_Y_RZ_CPS_50mHz_800Hz_2011_04_05.fig
- LLO_HAM_ISI_Unit_3_TF_C2C_X_Y_RZ_GS13_50mHz_800Hz_2011_04_05.fig

- LLO_HAM_ISI_Unit_3_TF_C2C_Z_RX_RY_CPS_50mHz_800Hz_2011_04_05.fig
- LLO_HAM_ISI_Unit_3_TF_C2C_Z_RX_RY_GS13_50mHz_800Hz_2011_04_05.fig

Storage of measured transfer functions in the SVN at:

/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Transfer_functions/Cartesian_to_Cartesian

- LLO_HAM_ISI_Unit_3_Data_TF_C2C_2011_04_05

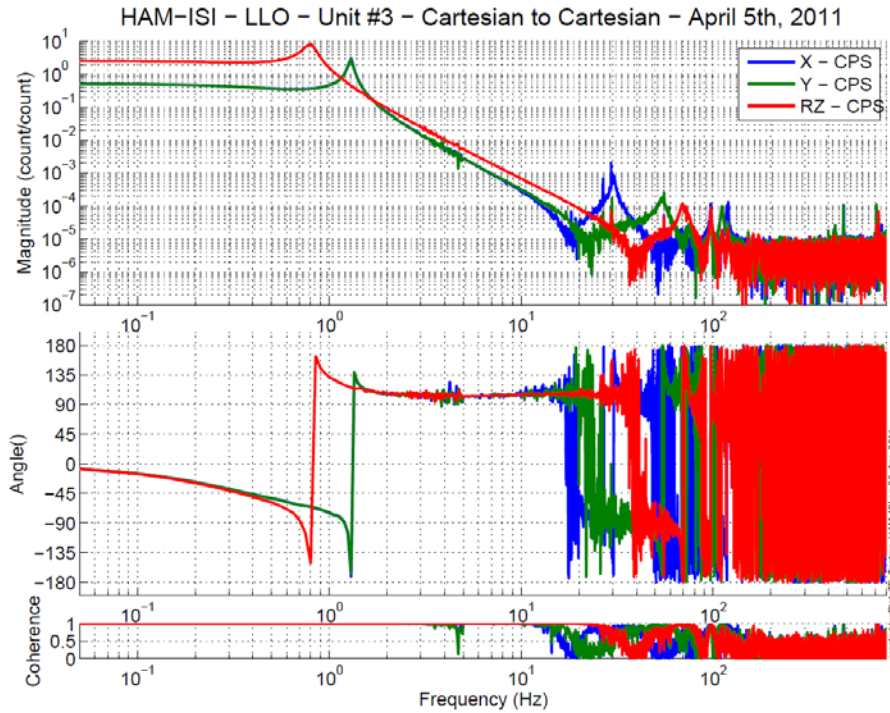


Figure - Cartesian to Cartesian CPS measurements – X, Y, RZ directions

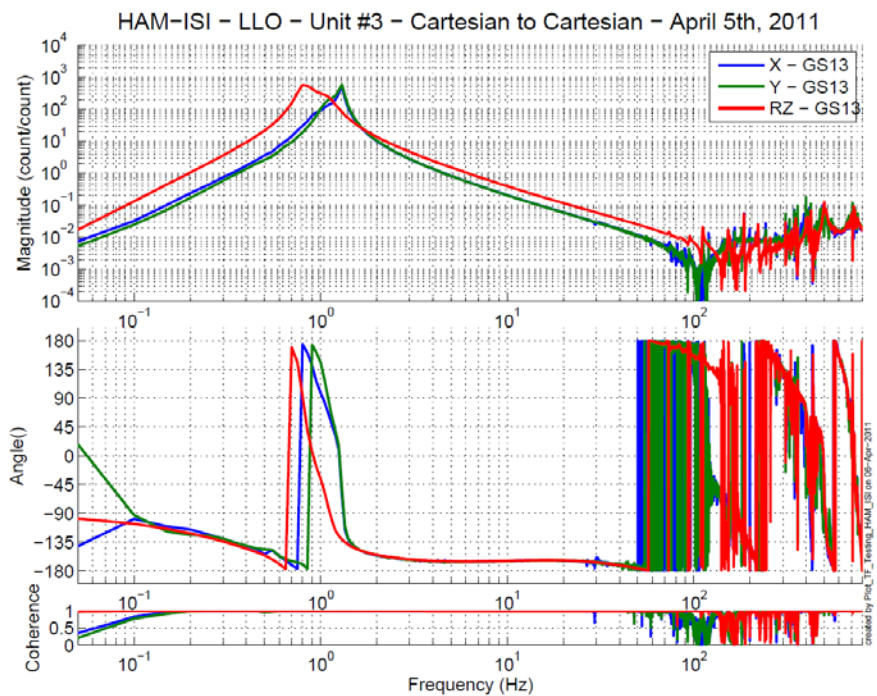


Figure - Cartesian to Cartesian GS-13 measurements – X, Y, RZ directions

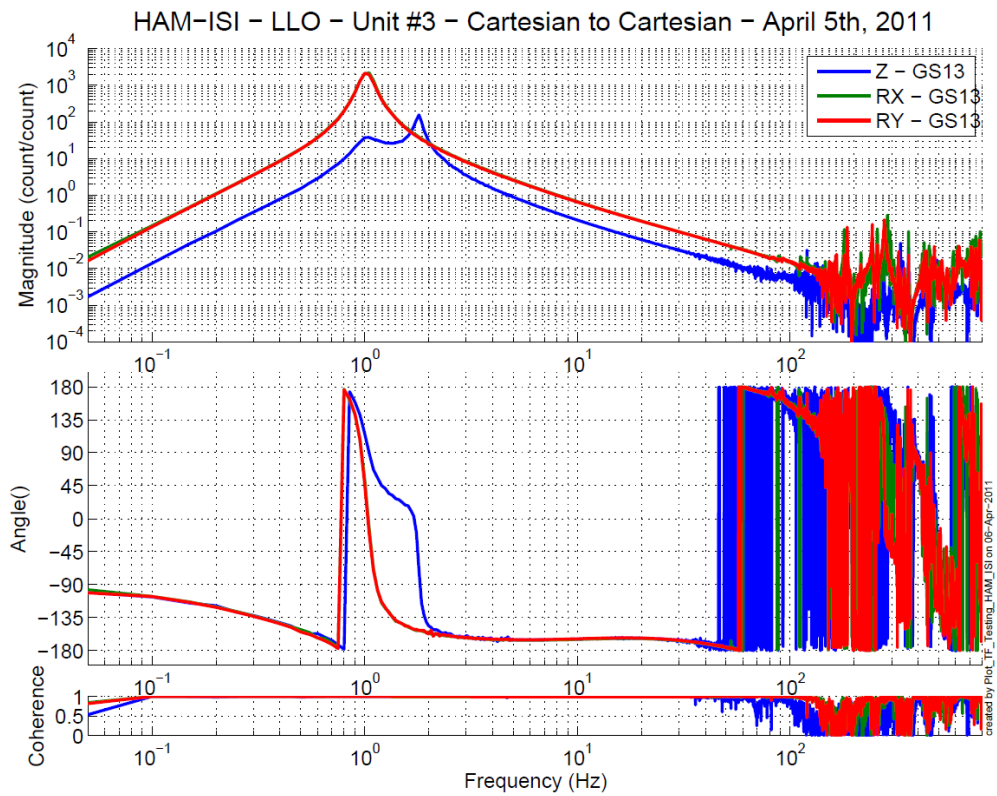
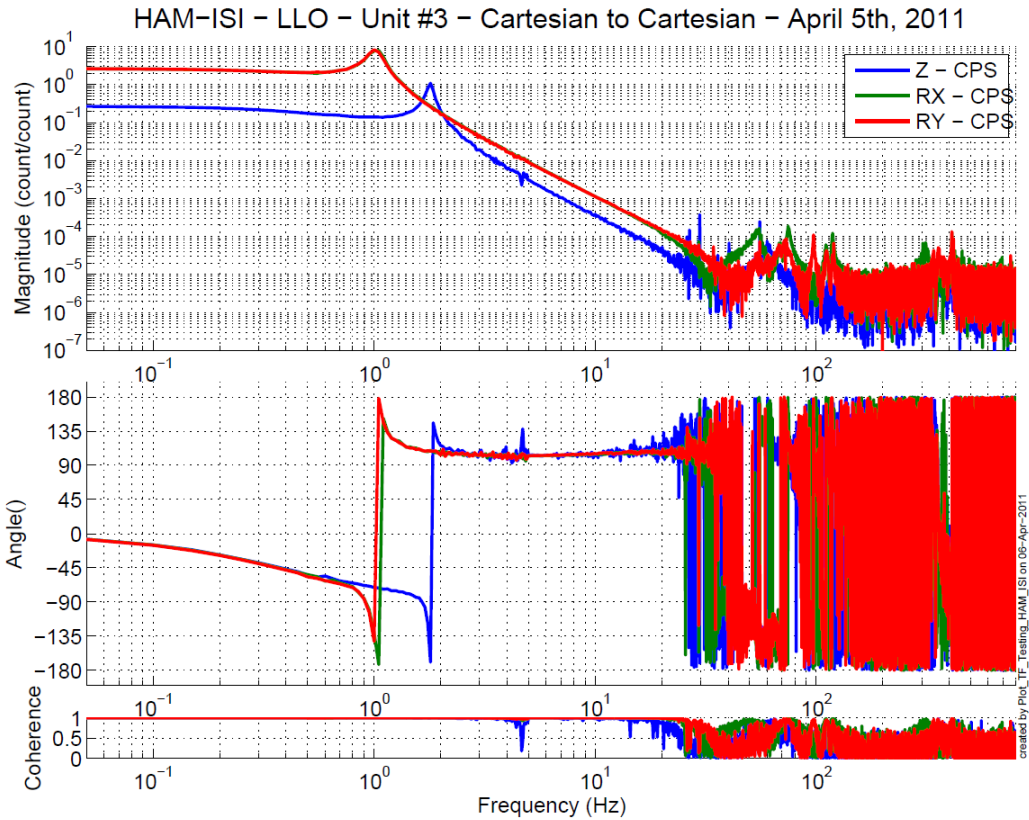


Figure - Cartesian to Cartesian measurements - Z, RX, RY directions

Issues/difficulties/comments regarding this test:

Acceptance criteria:

- Local to local measurement
 - o On CPS, the phase must be 0° at DC
 - o On Geophones, the phase must be -90° at DC
- Cartesian to cartesian measurement
 - o On CPS, the phase must be 0° at DC
 - o On Geophones, the phase must be -90° at DC

Test result:

Passed: X

Failed:

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

Scripts files for processing and plotting in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Transfer_Functions/Measurements/
Undamped/

- Plot_LLO_HAM_ISI_Unit_3_TF_L2L_2011_04_06.m

Local to local figures in SVN at:

/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Figures/Transfer_Functions/Measurements/

- LLO_HAM_ISI_Unit_3_TF_L2L_H_CPS_50mHz_800Hz_wHAM6_2011_04_06.fig
- LLO_HAM_ISI_Unit_3_TF_L2L_V_CPS_50mHz_800Hz_wHAM6_2011_04_06.fig
- LLO_HAM_ISI_Unit_3_TF_L2L_H_GS13_50mHz_800Hz_wHAM6_2011_04_06.fig
- LLO_HAM_ISI_Unit_3_TF_L2L_V_GS13_50mHz_800Hz_wHAM6_2011_04_06.fig

GS13, Local to local measurement

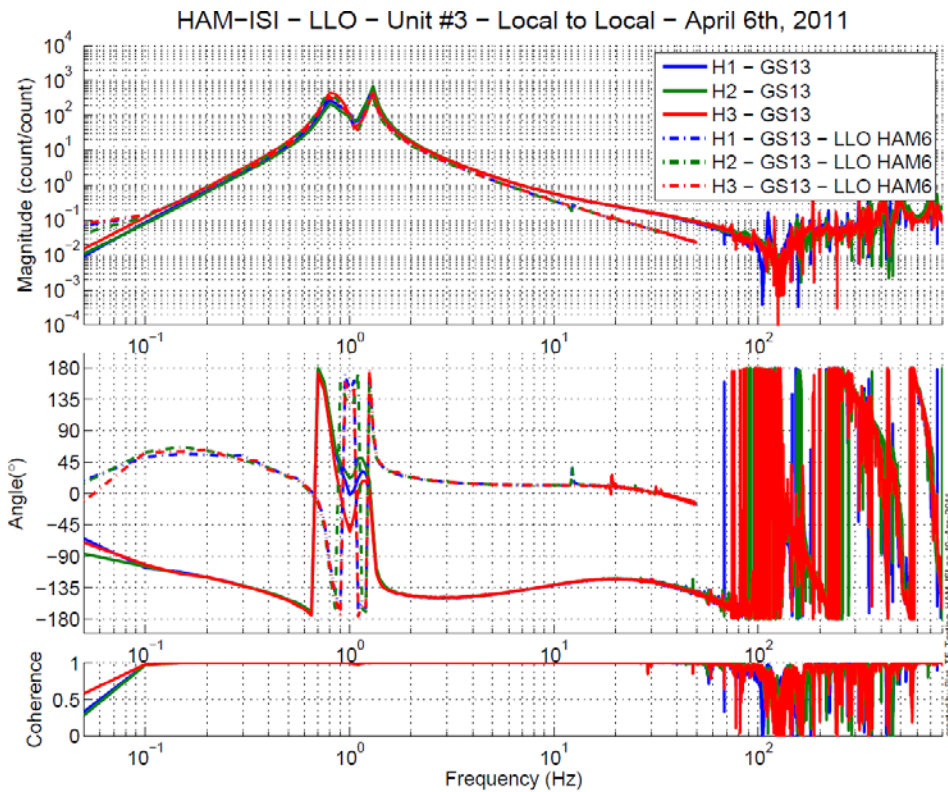


Figure - Local to local measurements comparison with HAM6 – Horizontal GS13

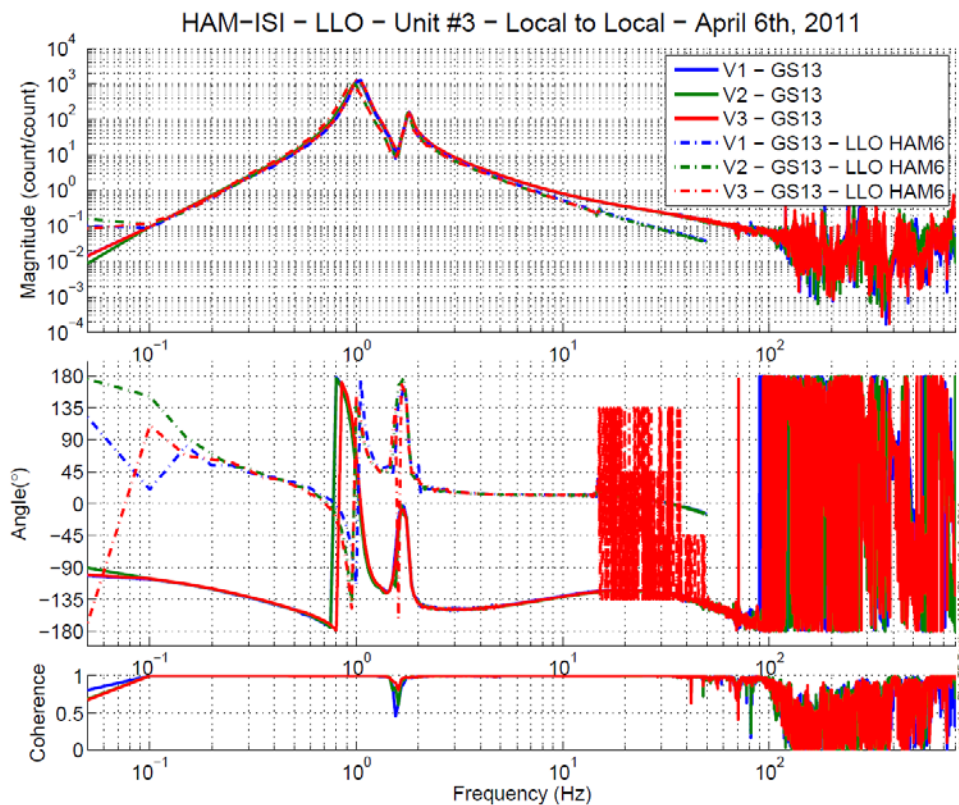


Figure - Local to local measurements comparison with HAM6 – Vertical GS13

CPS, Local to local measurement, Undamped

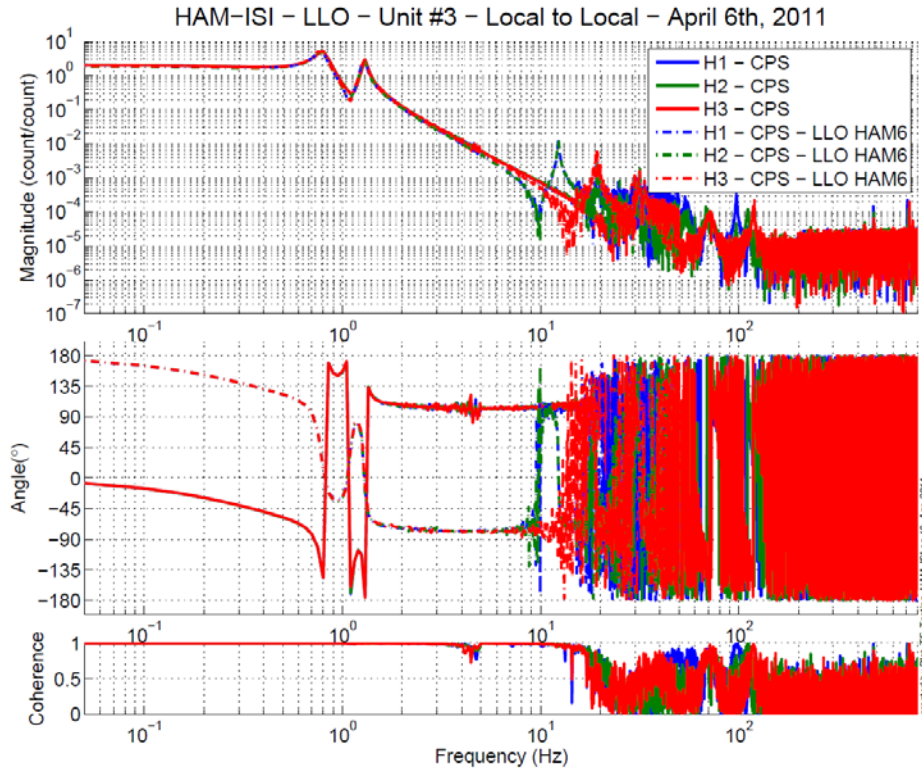


Figure - Local to local measurements comparison – Horizontal Position sensors

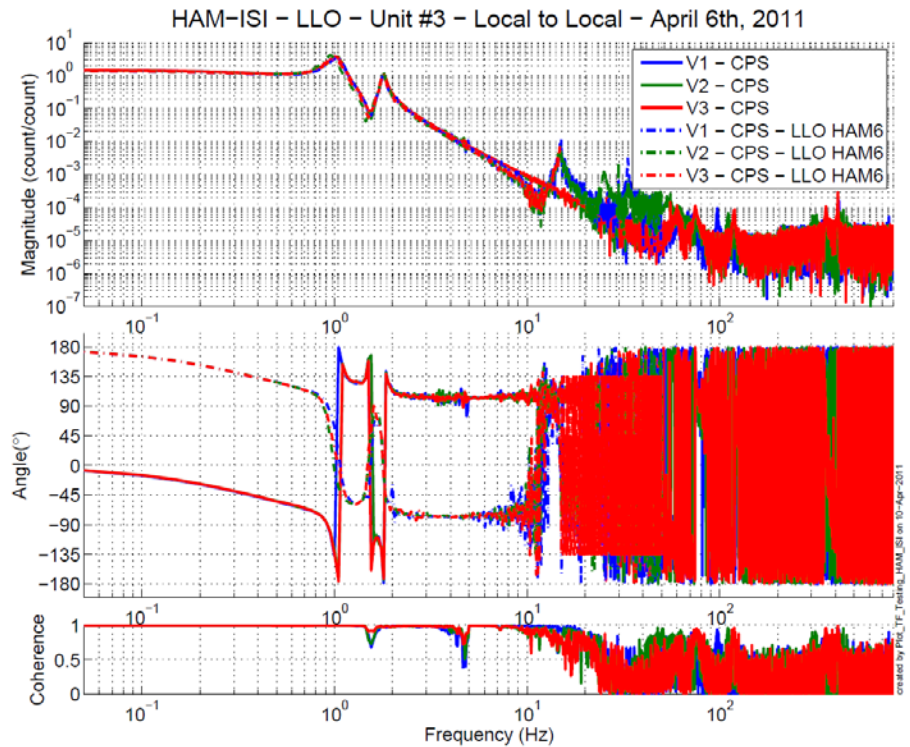


Figure - Local to local measurements comparison – Horizontal Position sensors

Difference with HAM6:

- Sign difference on CPS and Geophones.

o *Step 18.2 - Cartesian to Cartesian - Comparison with HAM6*

Scripts files for processing and plotting in SVN at:

opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Transfer_Functions/Measurements/Undamped/

- Plot_LLO_HAM_ISI_Unit_3_TF_C2C_2011_04_06.m

Cartesian to Cartesian figures in SVN at :

/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Transfer_functions/Cartesian_to_Cartesian

- LLO_HAM_ISI_Unit_3_TF_C2C_X_Y_RZ_CPS_50mHz_800Hz_wHAM6_2011_04_05.fig
- LLO_HAM_ISI_Unit_3_TF_C2C_Z_RX_RY_CPS_50mHz_800Hz_wHAM6_2011_04_05.fig
- LLO_HAM_ISI_Unit_3_TF_C2C_X_Y_RZ_GS13_50mHz_800Hz_wHAM6_2011_04_05.fig
- LLO_HAM_ISI_Unit_3_TF_C2C_Z_RX_RY_GS13_50mHz_800Hz_wHAM6_2011_04_05.fig

GS13, Cartesian to Cartesian measurement, Undamped

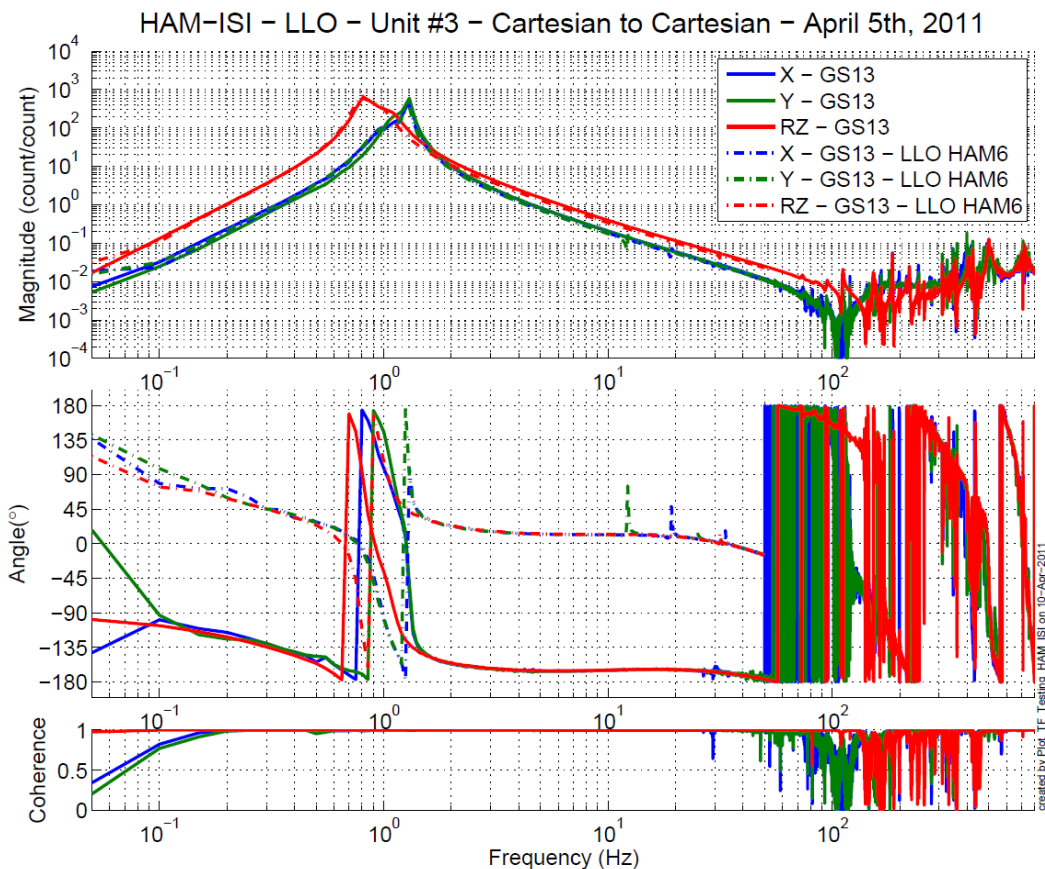


Figure - Cartesian to Cartesian measurements comparison with HAM6 – Horiz GS13

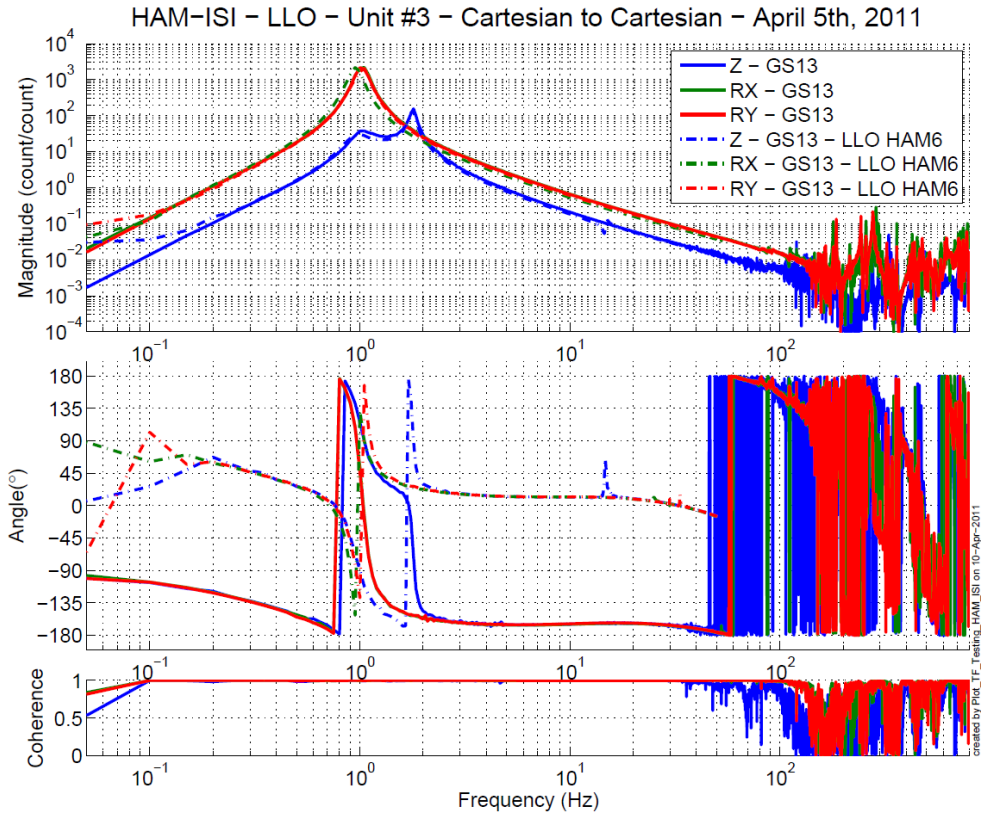


Figure - Cartesian to Cartesian measurements comparison with HAM6 – Vertical GS13

CPS, Cartesian to Cartesian measurement, Undamped

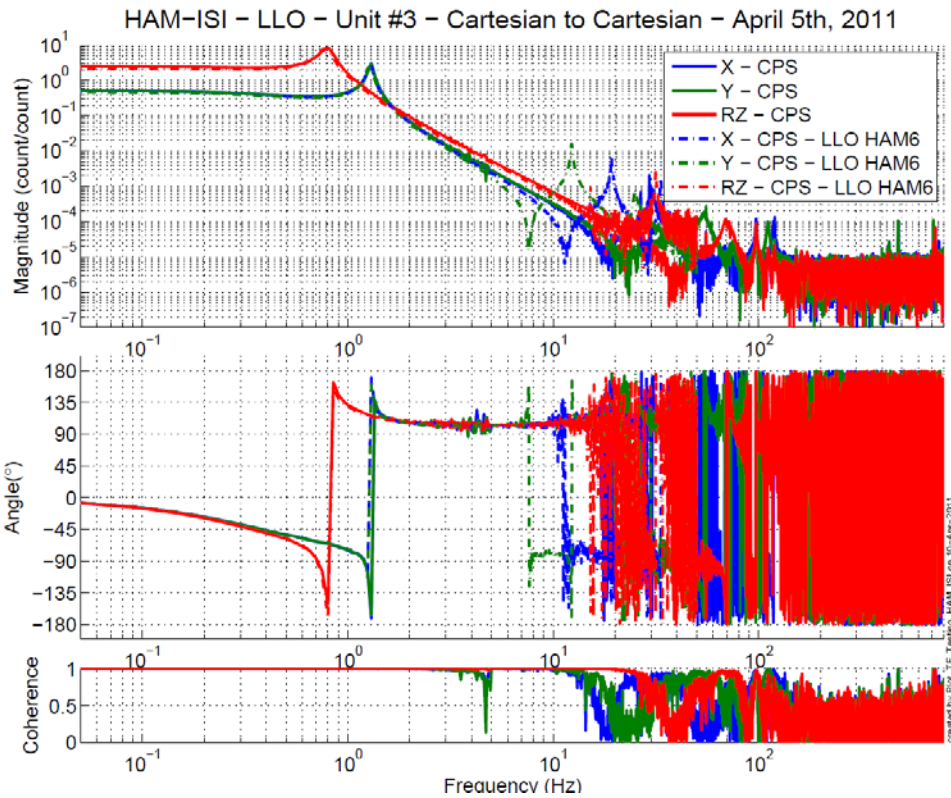


Figure - Cartesian to Cartesian measurements comparison – Horizontal Position sensors

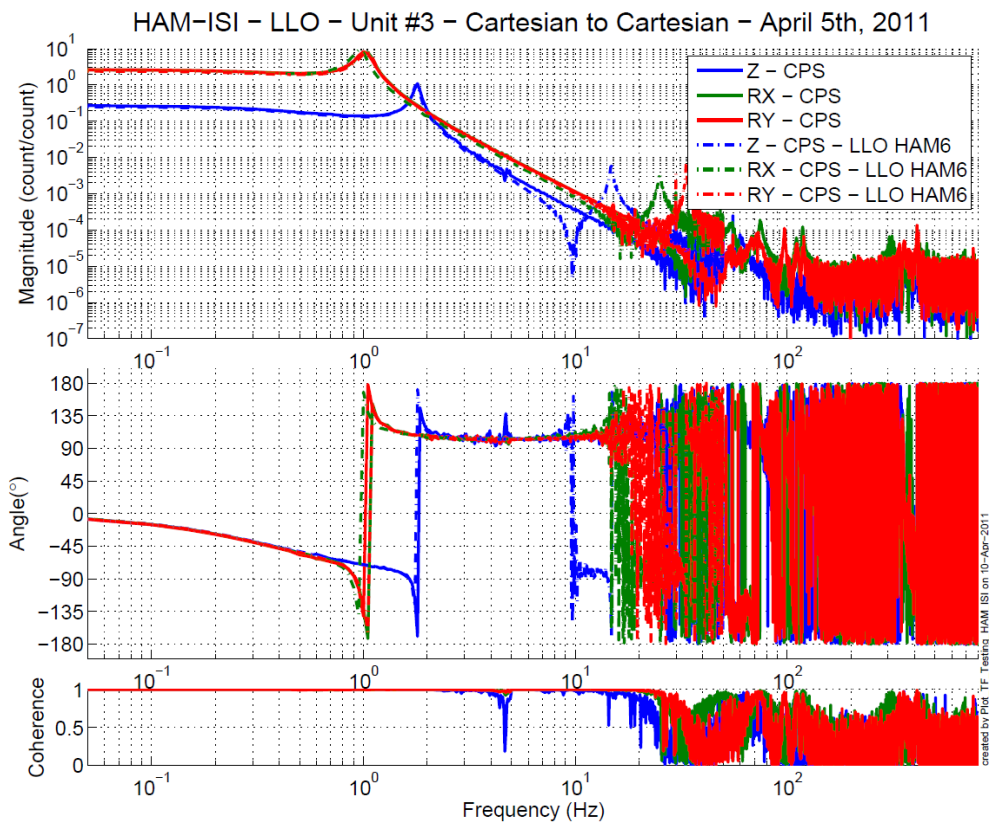


Figure - Cartesian to Cartesian measurements comparison – Vertical Position sensors

Difference with HAM6:

- Resonance at 1 Hz is slightly higher than HAM6
- Sign difference on Geophones

Acceptance criteria:

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

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

▪ **Step 19 - 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_3/Transfer_Functions/Measurements/Undamped/

- LZMP_LLO_HAM-ISI-Unit_3_2011_04_06.mat

Scripts files for processing and plotting in SVN at:

opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Transfer_Functions/Measurements/Undamped/

- LZMP_2011_04_06.m

Figures in SVN at:

opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Figures/Transfer_Functions/Measurements/Undamped/

- LZMP.fig

X & Y offsets:

X offset (mm)	0.399
Y offset (mm)	0.738

Table – Offset of the Lower Zero Moment Plane

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

HAM-ISI – LLO – Unit #3 – Cartesian to Cartesian – April 6th, 2011

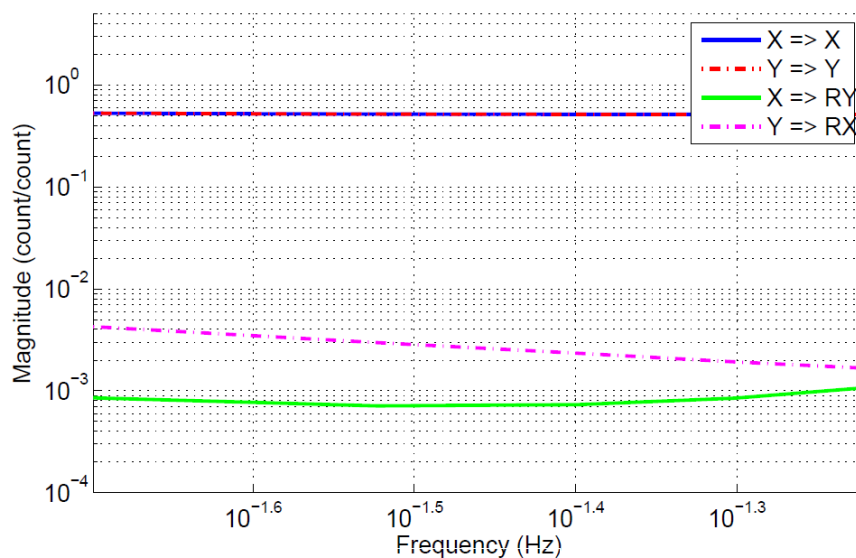


Figure - Lower Zero moment plane – Main and cross couplings at low frequency

Acceptance criteria:

- X offset must be less than 1 mm
- Y offset must be less than 1mm

Test result:

Passed: X

Failed:

▪ **Step 20 - Damping loops**

Filters used by Damping loops in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X1/FilterDesign/Unit_3/txt_file

- G11SIHAM_Back_up_2010_09_01.txt (digitalized filters copied and rename to G11SIHAM.txt in /opt/rtdcs/geo/g1/chans)

○ **Step 20.1 - Transfer functions - Simulation**

Scripts files for processing and plotting in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Transfer_Functions/Simulation/Damping

- HAM_ISI_LLO_Unit_3_Damping_TF_2011_04_18.m

Figures in SVN at:

/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/Transfer_Functions/Simulations/Damping/

- Damping_LOOP_H1_H2_H3.fig
- Damping_LOOP_V1_V2_V3.fig

Results are saved in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/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.

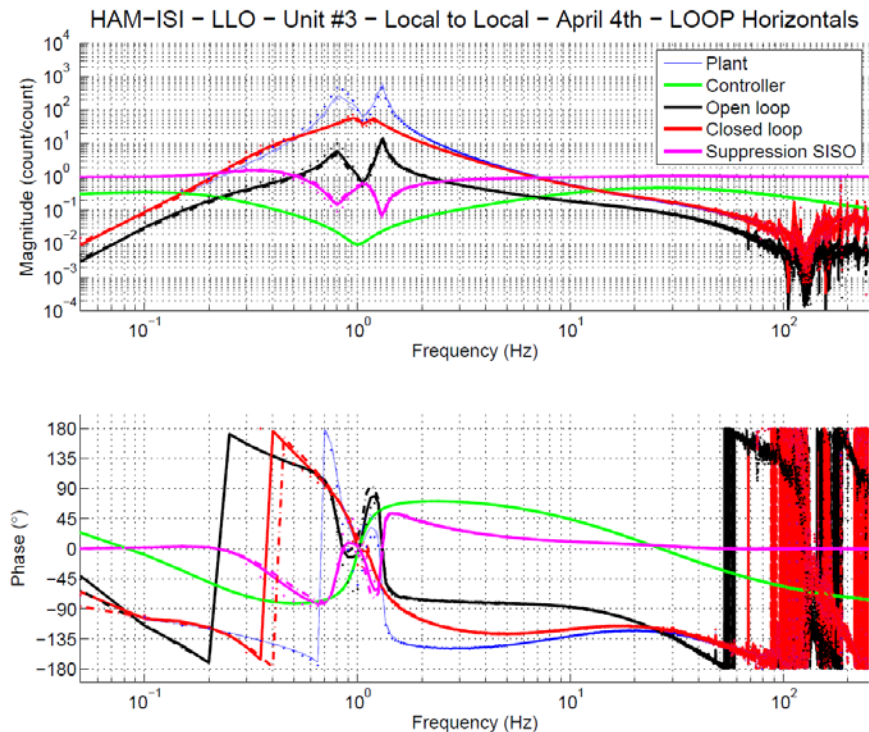


Figure - Horizontal damping loops - Simulation

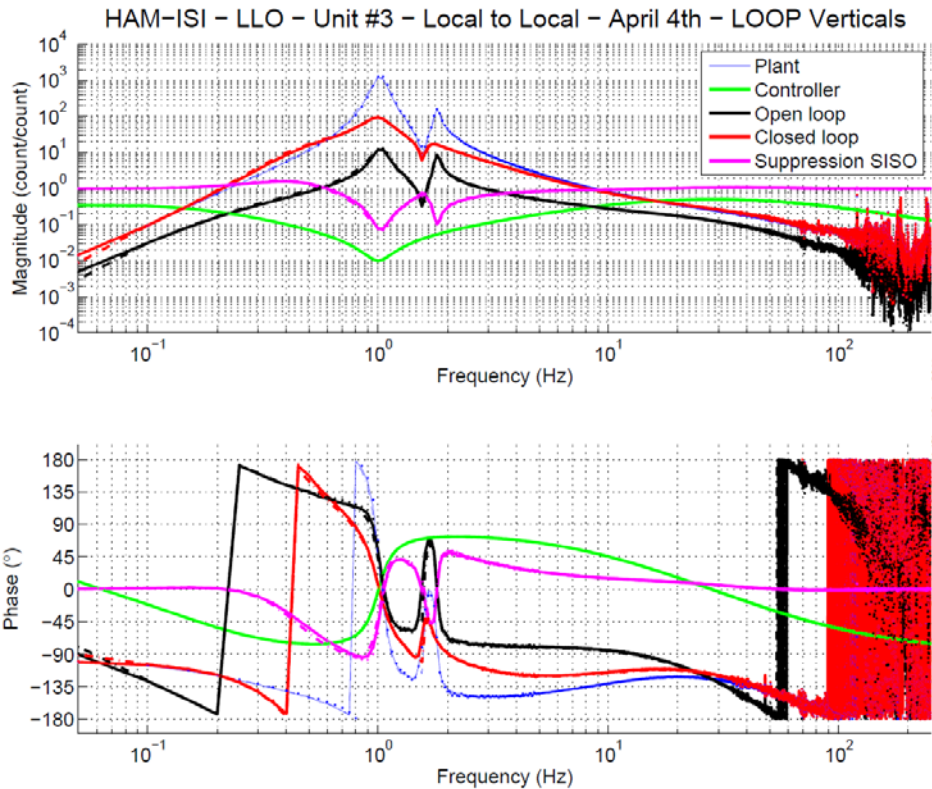


Figure - Vertical damping loops - Simulation

○ *Step 20.2 - Powerspectrum – Experimental*

Data files in SVN at:

/opt/svncommon/seisvn/seismic/HAM-ISI/X2/Data/Unit_3/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_3/Figures/Powerspectra/Damping/

- LLO_HAM_ISI_Unit_3_Calibrated_PSD_CPS_Undamped_Damped_2011_04_08.fig
- Simulation_vs_experimental_Suppression.fig

Powerspectrum:

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

LLO HAM-ISI-Unit 3 - Powerspectra GS13 - 2011 04 08

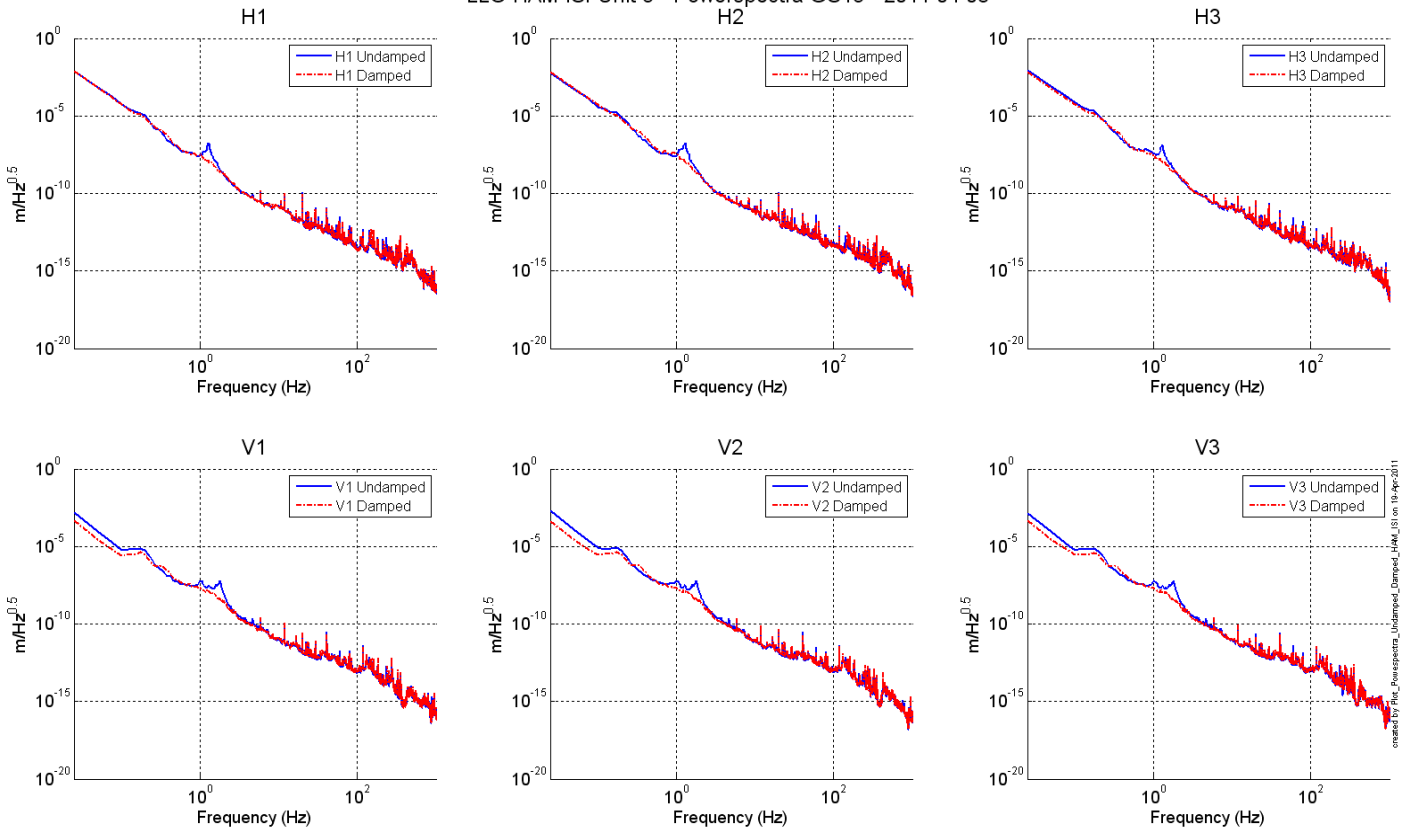


Figure – Horizontal (top) and vertical (bottom) damping loops - Experimental

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.

LLO HAM-ISI-Unit 3 - Experimental vs simulated suppression - 2011 04 18

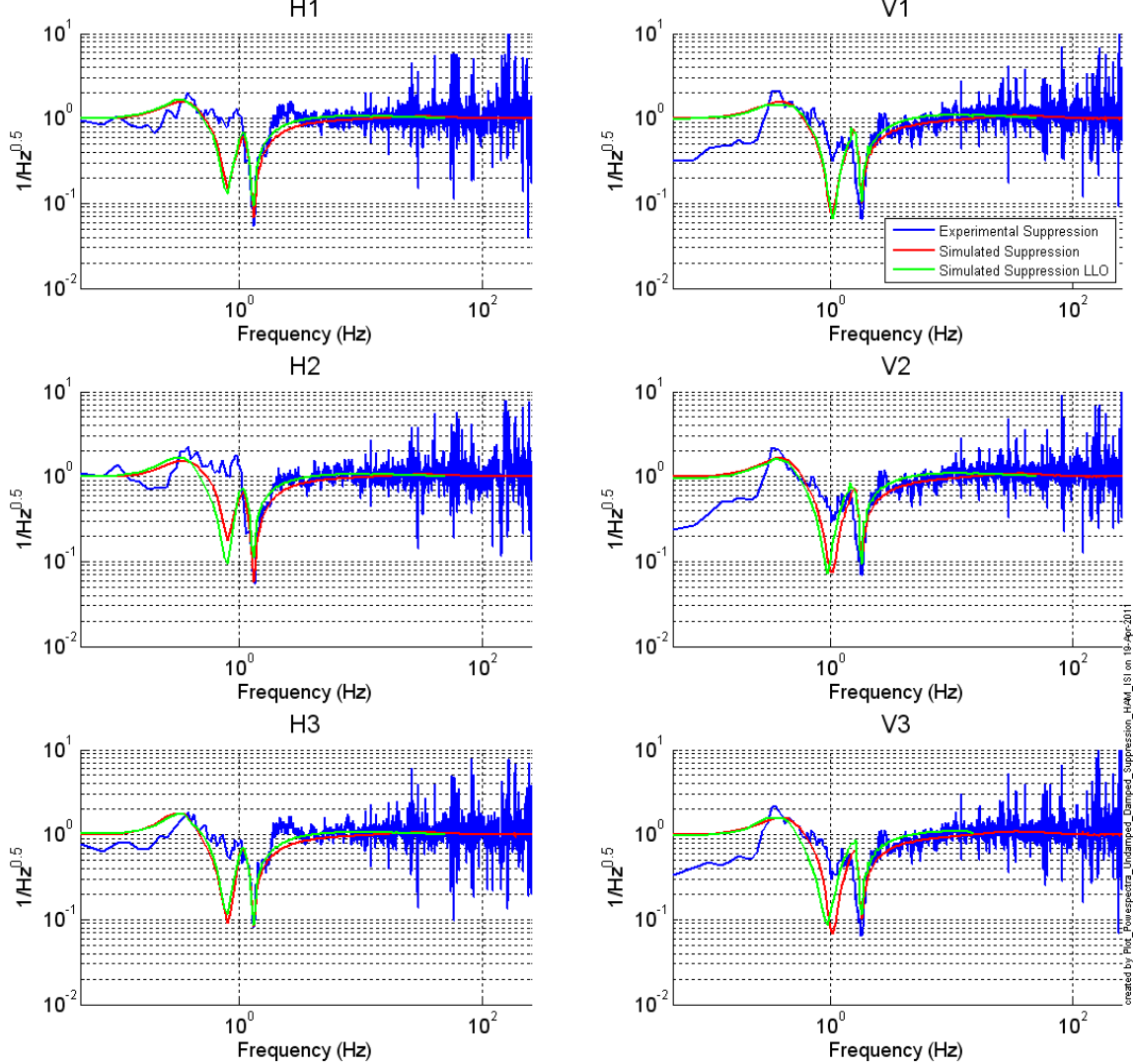


Figure – Horizontal (left) and vertical (right) damping loops - Experimental

Acceptance criteria:

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

Test result:

Passed: X

Failed: