LIGO Laboratory / LIGO Scientific Collaboration

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aLIGO BSC-ISI Unit 5, Pre-integration Testing report, Phase I (post-assembly)

E1100308 – V1

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Distribution of this document:
Advanced LIGO Project

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Introduction

The BSC-ISI testing is performed in three phases:
1) BSC-ISI, Pre-integration Testing, Phase I (post-assembly)
2) BSC-ISI, Pre-integration Testing, Phase II: Tests done after Transport (and possible storage), during mating phase with Suspensions, before insertion.
3) BSC-ISI, Integration Phase Testing: Procedure and results related to the commissioning in the chamber.

This document presents the series of tests (Phase I) performed on the ISI-BSC5 (ETMY) in the High Bay before its move to the Y-end (Test stand). These tests were done in April 2013.

This is the fifth and last "aLigo BSC-ISI" built and tested with the "aLigo electronic" at the LLO site. The testing procedure document E1000486-v3 was used.

All results are posted on the SVN at:
https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/X2/Data/BSC5/

The following type of document can be found in the SVN:
- Excel spreadsheet (.xls)
- Data location
- Figures location
- Masses distribution scheme (ppt)

I. Pre-Assembly Testing

- ***Step 1 - CPS Test and calibration – E1100369***

CPS sensors are tested (calibration and noise test) at MIT before being cleaned and baked at LLO. The list of installed sensors used for testing (phase I) are reported in step II.3.

All data related to the CPS testing can be found in the SVN at
/svn/seismic/Common/Data/aLIGO_BSC_ISI_CPS/

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

- ***Step 2 - GS13 – Inspection/Assembly – E1000058 – E1100740***

GS13 are tested and podded at LLO.
The list of installed sensors used for testing (phase I) are reported in step II.3.

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

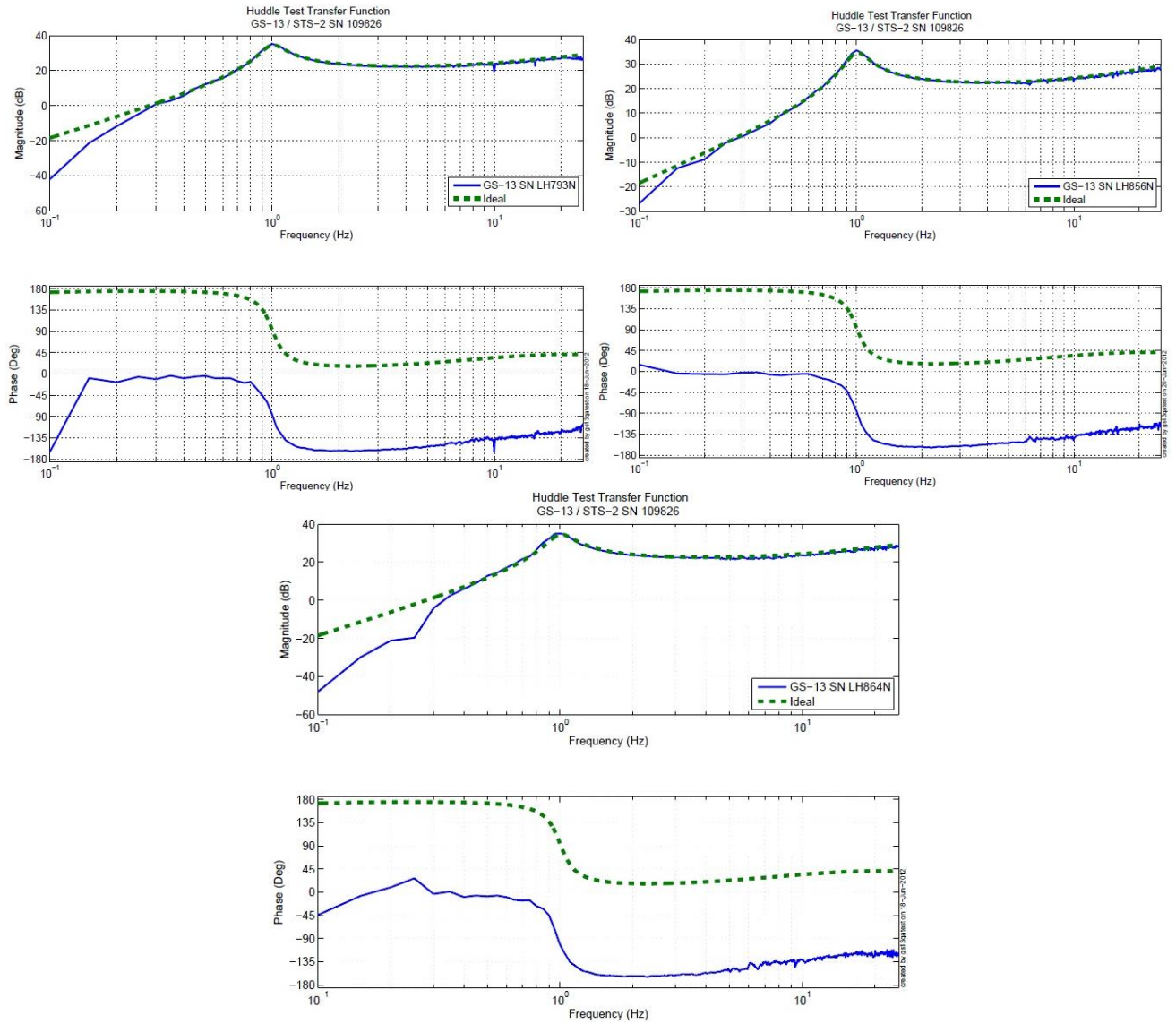

Figure 1: Huddle Test Transfer Function of the Horizontal GS-13 SN 793, 856 & 864 after aLIGO modifications

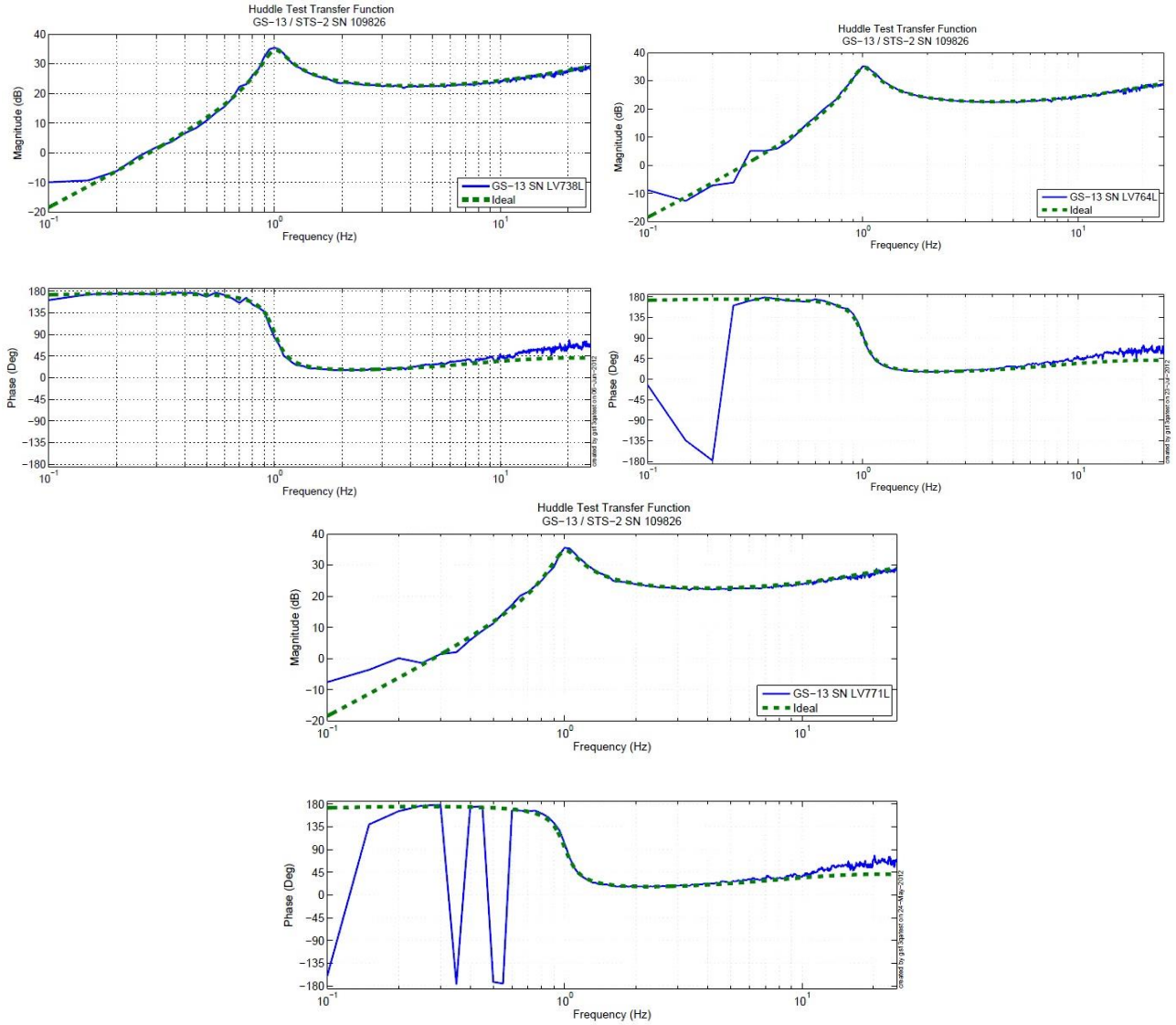

Figure 2: Huddle Test Transfer Function of the Vertical GS-13 SN 738, 764 & 771 after aLIGO modifications

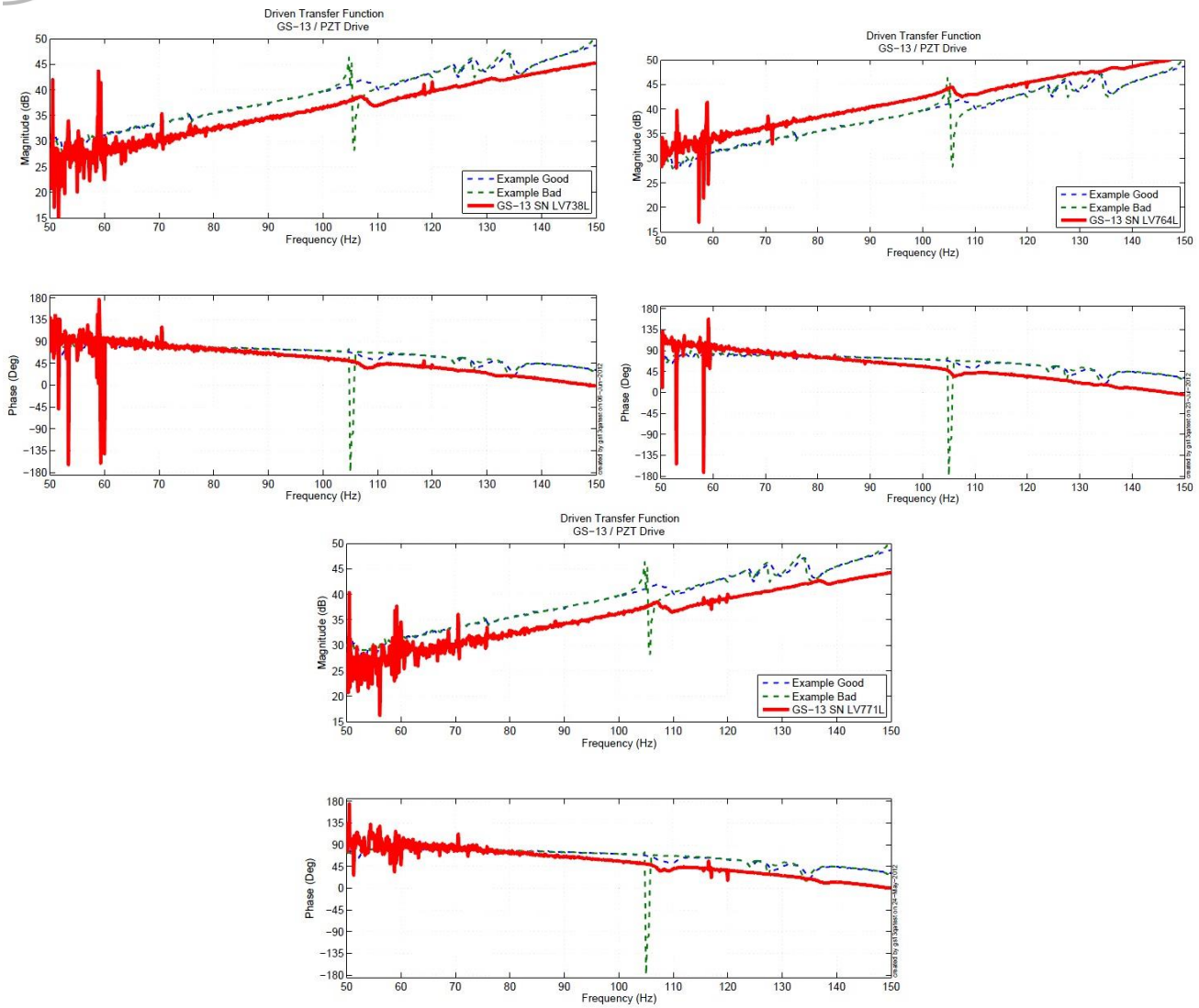

Figure 3: Driven Transfer Function of the Vertical GS-13 SN 738, 764 & 771 after aLIGO modifications

E1000058 and E1100740 spreadsheets provide the status of each individual GS-13 at LLO site for HAM-ISI and BSC-ISI and the installation location of the geophones.

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

- ***Step 3 - L4C – Inspection/Assembly – E1000136 – E1100740***

L4C are tested and podded at LLO. The list of installed sensors used for testing (phase I) are reported in step II.3.

All the data related to L4C post podding testing can be found in the SVN at:
/svn/seismic/Common/Data/aLIGO_L4C_TestData/TestResults_PDFs/

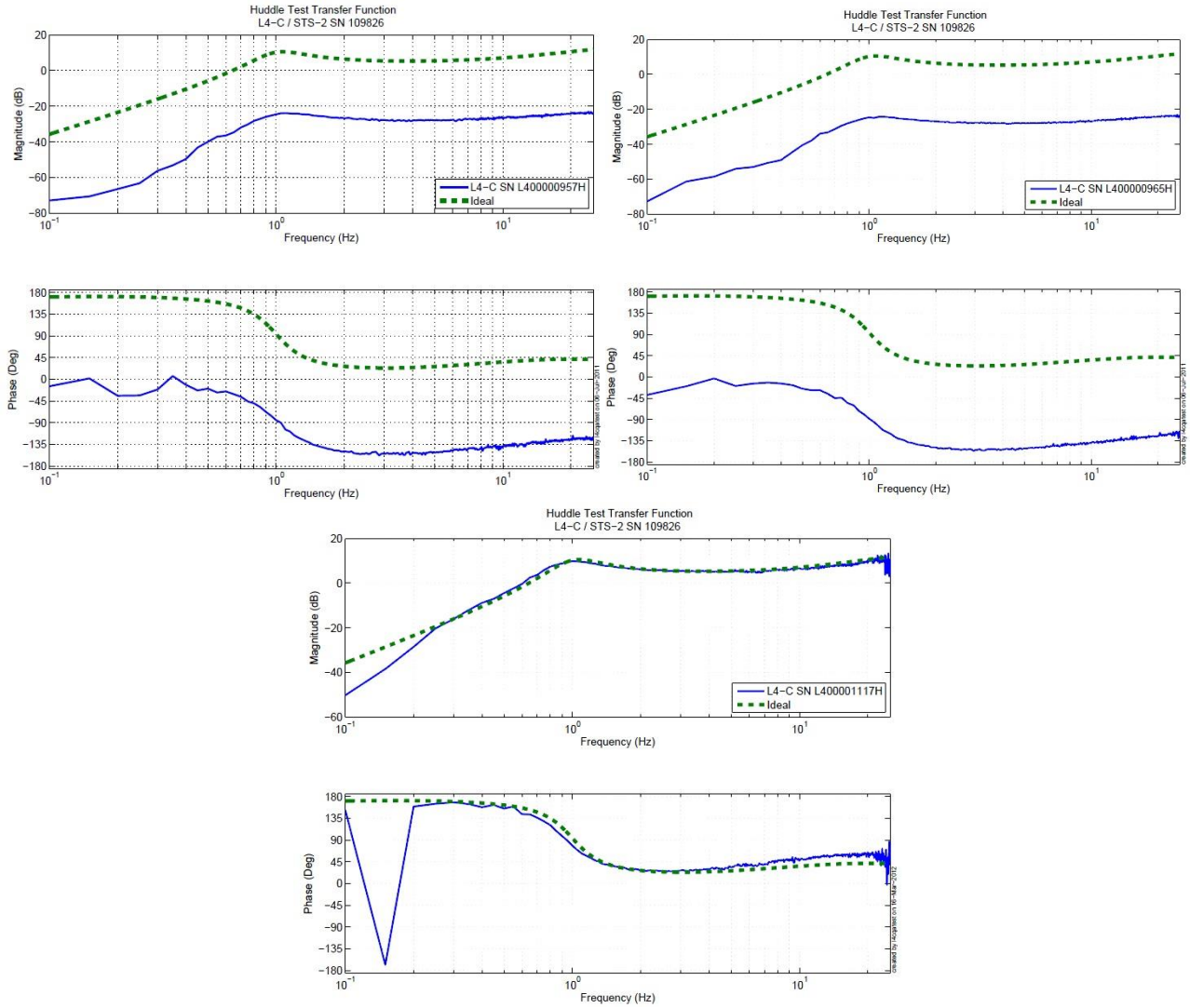

Figure 4: Huddle Test Transfer Function of the Horizontal L4-C SN 957, 965 & 1117

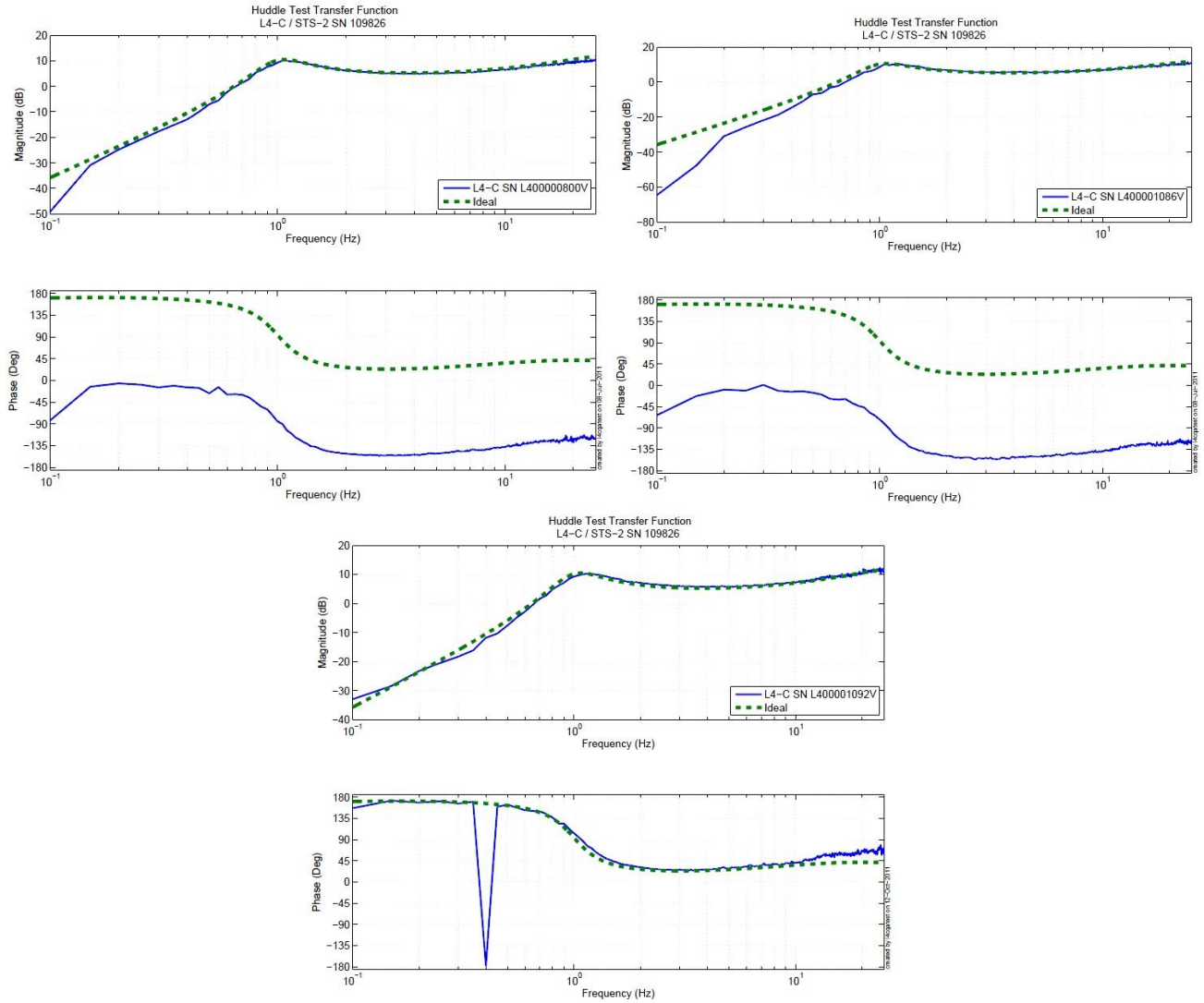

Figure 5: Huddle Test Transfer Function of the Vertical L4-C SN 800, 1086 & 1092

E1000136 and E1100740 spreadsheets provide the status of each individual L4C at LLO site for HAM-ISI and BSC-ISI and the installation location of the geophones.

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

Step 4 - T240 – Inspection/Assembly - E1100326 – E1100740

T240 are tested and podded at LLO. We haven't had to replace the T240s on this Unit, and these are the ones with the new Voltage Regulator, it seems that they are working fine and keep the pressure sensor from dying. The list of installed sensors used for testing (phase I) are reported in step II.3.

All the data related to T240 post podding testing can be found in the SVN at:
seismic/Common/Data/aLIGO_T240_TestData/AsReceived_TestResults_PDFs.

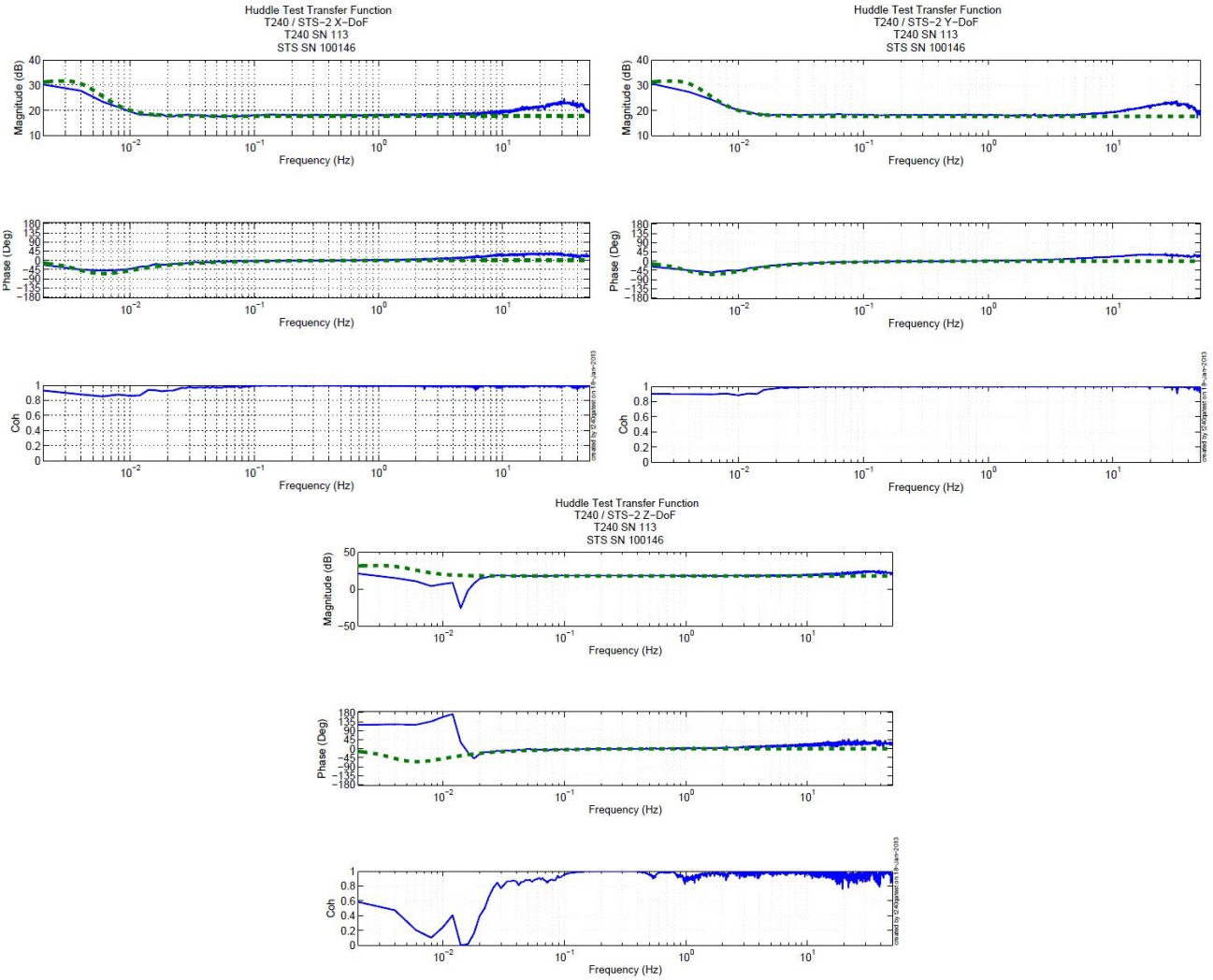

Figure 6: Huddle Test Transfer Function of the X, Y & Z axis of the T240 SN 113

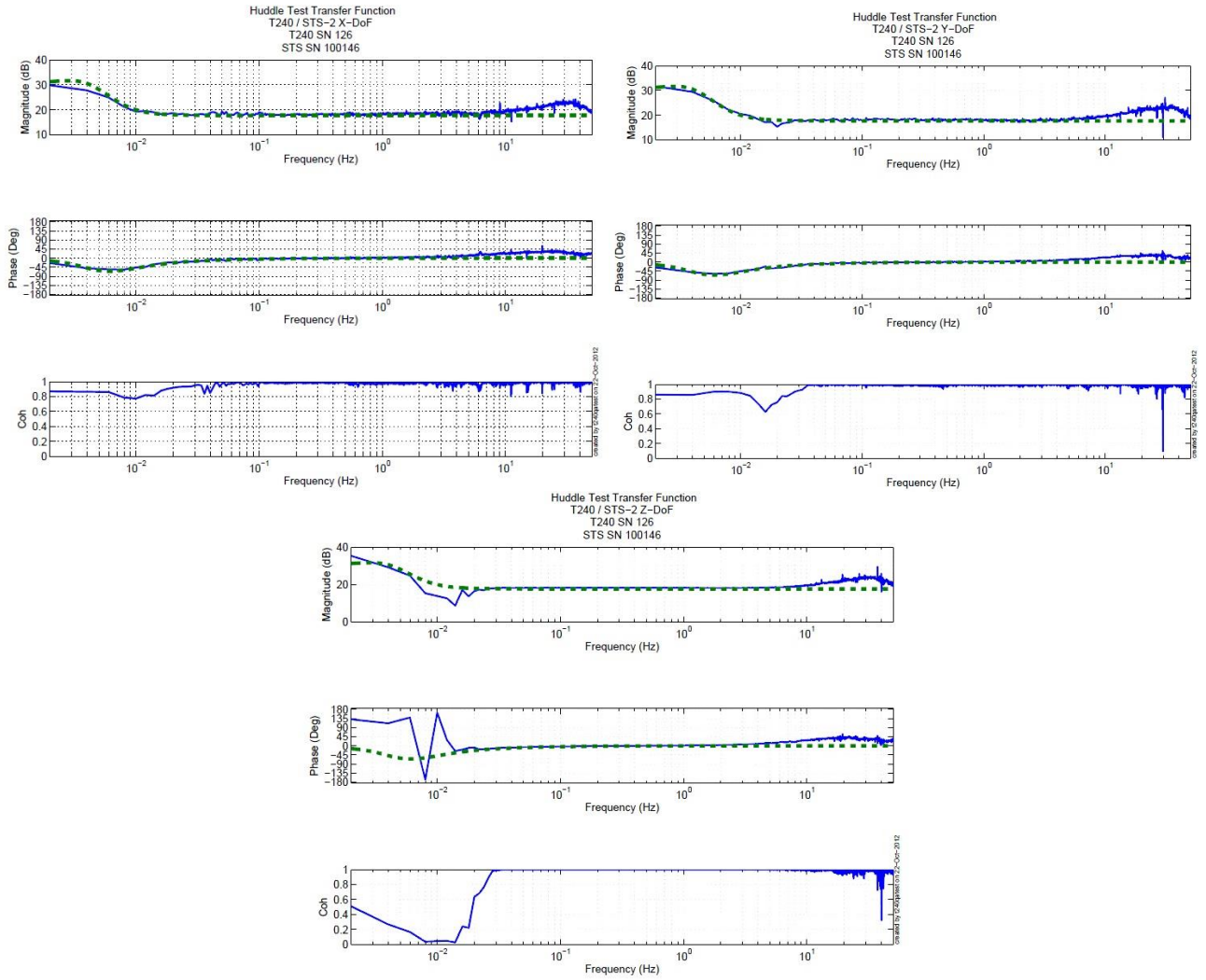

Figure 7: Huddle Test Transfer Function of the X, Y & Z axis of the T240 SN 126

Figure 8: Huddle Test Transfer Function of the X, Y & Z axis of the T240 SN 149

E1100326 and E1100740 spreadsheets provide the status of each individual T240 at LLO site for BSC-ISI and the installation location of the geophones.

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

- ***Step 5 - Actuators - T0900564 - T1100234 – E1100741***

The list of installed sensors used for testing (phase I) are reported in step II.2
Large actuators data can be found at: T0900564. Actuator inventory is made at Section II – Step 2.
Small actuators data can be found at: T1100234. Actuator inventory is made at Section II – Step 2.

	Stage 0-1	Stage 1-2
H1	Actuator Serial #: L017 Operator Name: Smith, Lane Date: 8/11/2009 Time: 3:54 PM Actuator Coil Resistance: 6.33 Ohms, PASS Ambient Temperature: 74.2 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.516 Y Travel Limit (inches): 0.196 Z Travel Limit (inches): 0.480	Actuator Serial #: S029 Operator Name: Gordon, Matt Date: 7/29/2010 Time: 3:55 PM Actuator Coil Resistance: 10.21 Ohms, PASS Ambient Temperature: 79.7 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.661 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.503
H2	Actuator Serial #: L075 Operator Name: Gordon, Matt Date: 11/22/2009 Time: 1:30 PM Actuator Coil Resistance: 6.32 Ohms, PASS Ambient Temperature: 70.4 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.532 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.506	Actuator Serial #: S084 Operator Name: Gordon, Matt Date: 4/14/2011 Time: 8:42 AM Actuator Coil Resistance: 10.45 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.660 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.512
H3	Actuator Serial #: L043 Operator Name: Gordon, Matt Date: 9/24/2009 Time: 3:07 PM Actuator Coil Resistance: 6.36 Ohms, PASS Ambient Temperature: 75.8 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.531 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.505	Actuator Serial #: S085 Operator Name: Gordon, Matt Date: 4/14/2011 Time: 9:00 AM Actuator Coil Resistance: 10.55 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.658 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.513
V1	Actuator Serial #: L023 Operator Name: Smith, Lane Date: 8/12/2009 Time: 9:26 AM Actuator Coil Resistance: 6.42 Ohms, PASS Ambient Temperature: 68.8 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.518 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.478	Actuator Serial #: S023 Operator Name: Gordon, Matt Date: 7/28/2010 Time: 4:53 PM Actuator Coil Resistance: 10.33 Ohms, PASS Ambient Temperature: 79.0 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.651 Y Travel Limit (inches): 0.207 Z Travel Limit (inches): 0.502
V2	Actuator Serial #: L041 Operator Name: Hartmann Donna Date: 9/23/2009 Time: 10:05 AM Actuator Coil Resistance: 6.37 Ohms, PASS Ambient Temperature: 72.9 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.523 Y Travel Limit (inches): 0.207 Z Travel Limit (inches): 0.506	Actuator Serial #: S026 Operator Name: Gordon, Matt Date: 7/23/2010 Time: 5:30 AM Actuator Coil Resistance: 10.23 Ohms, PASS Ambient Temperature: 69.8 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.645 Y Travel Limit (inches): 0.206 Z Travel Limit (inches): 0.503
V3	Actuator Serial #: L061 Operator Name: Gordon, Matt Date: 9/23/2009 Time: 5:09 PM Actuator Coil Resistance: 6.35 Ohms, PASS Ambient Temperature: 72.5 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	Actuator Serial #: S079 Operator Name: Gordon, Matt Date: 4/13/2011 Time: 2:16 PM Actuator Coil Resistance: 10.42 Ohms, PASS Ambient Temperature: 75.6 F Hi Pot Test Results: 1000 MOhms, PASS X Travel Limit (inches): 0.664 Y Travel Limit (inches): 0.205 Z Travel Limit (inches): 0.514

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

II. Tests to be performed during assembly

- ***Step 1 - Test stand level***

The HAM-ISI Test Stand was transformed and re-leveled to dock a BSC-ISI.

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

- ***Step 2 - Actuators Inventory***

The actuators S/N are reported in the table below. Further information can be found in T0900564 and T1100234.

Stage 0-1		Stage 1-2	
Actuator	**Actuator S/N**	**Actuator**	**Actuator S/N**
H1	L017	**H1**	S029
H2	L075	**H2**	S084
H3	L143	**H3**	S085
V1	L023	**V1**	S023
V2	L041	**V2**	S026
V3	L061	**V3**	S079

Table 1 - Actuators' inventory

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

- ***Step 3 - Sensors Inventory***

The sensors S/N are reported in the table below.

CPS Stage 0-1	CPS S/N	ADE board serial #
H1	13227	12414
H2	12955	12837
H3	13188	12626
V1	13469	13077
V2	12906	12838
V3	13412	12501

Table 2 - Capacitive position sensors' inventory – Stage 1

CPS Stage 1-2	CPS S/N	ADE board serial #
H1	13529	12513
H2	12890	12852
H3	13231	12539
V1	13433	12412
V2	12911	13093
V3	13228	12586

Geophones GS13	Serial Number	POD
H1	856	28
H2	793	41
H3	864	503
V1	764	25
V2	738	81
V3	771	99

Table 3 - GS13 inventory

Geophones L4C	Serial Number	POD
H1	1117	54
H2	957	146
H3	965	149
V1	1092	16
V2	1086	61
V3	800	66

Table 4 - L4C inventory

Geophones T240	Serial Number	POD
1	149	27
2	126	44
3	113	502

Table 5 - T240 inventory

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

- ***Step 4 - Electronics Inventory***

Write down in the table below all serial numbers all the electronic equipment:

Hardware	LIGO reference	S/N
Interface Chassis - Corner 1	D1002432	S1102219
Interface Chassis - Corner 2		S1106356
Interface Chassis - Corner 3		S1106358
Anti-Alliasing Chassis - Corner 1	D1002693	S1106137
Anti-Alliasing Chassis - Corner 2		S1106138
Anti-Alliasing Chassis - Corner 3		S1106136
Anti-image Chassis	D070081	S1000249
Binary Input Chassis	D1001726	S1101287
Binary Input Chassis		S1101285
Binary Output Chassis	D1001728	S1101322
T240 Interface - Corner 1	D1002694	S1104420
T240 Interface - Corner 2		S1104422
T240 Interface - Corner 3		S1104426
I/O Chassis	n/a	XP 005
Coil driver Pod 1	D0902744	S1103354
Coil driver Pod 2		S1000316
Coil driver Pod 3		S1103313

Table 6 - Electronic equipment

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

- ***Step 5 - Check level of Stage 0 after top-bottom plate assembly***

Note: This test has not been performed

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

- ***Step 6 - Check gaps under the blade posts***

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

- ***Step 7 - Blade post shim thickness***

This table shows the shims thickness installed under the lockers.

Stage 0-1		Stage 1-2	
Lockers	**Shim thickness (mil)**	**Lockers**	**Shim thickness (mil)**
A	126	**A**	123
B	123	**B**	116
C	125	**C**	127

Table 7 - Shims thickness

Acceptance criteria: Both D0901805 Stage 0-1 Locker Shims & D0902551 Stage 1-2 Locker Shims goes from .110" up to .130" with an increment of .001".

So far (LHO 3 first Units and LLO 3 first Units):

	Max	Min	Average
Stage 0-1	.130"	.114"	.1248"
Stage 1-2	.133"	.114"	.1219"

The values of this LLO 5th Unit seem coherent with the ones of the previous Units.

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

- ***Step 8 - Blade 0-1 post launch angle***

This test has not been performed on LLO Unit 2.

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

- ***Step 9 - Gap checks on actuators***

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

- ***Step 10 - Mass budget***

The figure below presents the location of the masses on both stages.

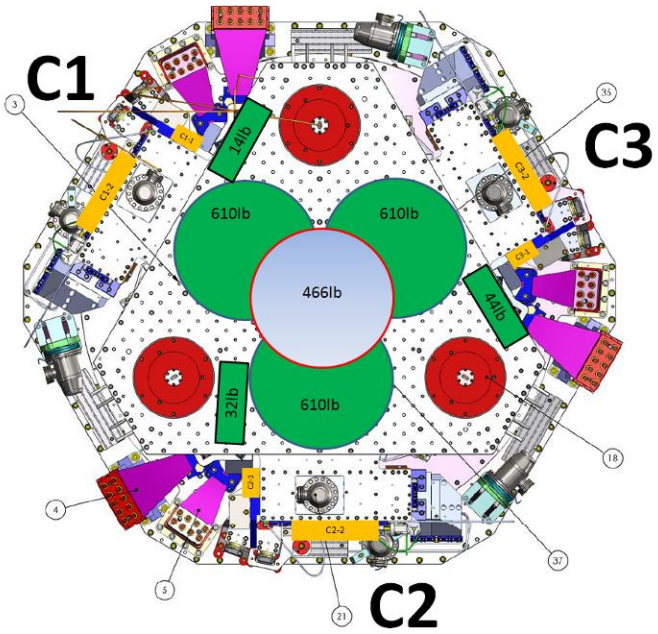

Figure 9: Masses distribution

Stage 1:

Stage 1		
Location	**Weight (lb)**	**Weight (Kg)**
C1-1	0	0.00
C1-2	0	6.80
C1-3	43.72	19.83
C2-1	0	0.00
C2-2	0	0.00
C2-3	39.22	17.79
C3-1	0	0.00
C3-2	0	0.00
C3-3	34.72	15.75
Total	**117.66**	**53.37**

Table 8 - Payload Stage 1

Nominal payload: 108.9Kg – 240lb
Added masses are 55.5Kg – 122.4lb lighter than expected.
Total mass of stage 1=929.5Kg - 2049lb

Stage 2:

4/1/2013	D972213	D972215	D0901075		D071200								
			5 kg	10 kg	00	01	02	03	04	05	06		
	610	230	11	22	0.6	1.1	2.2	4.5	7.9	15.6	27.2	lbs	kgs
A	1											610	276.69
B	1											610	276.69
C	1											610	276.69
D		2										460	208.65
E-1												0	0.00
E-2												0	0.00
E-3												0	0.00
F1										1	2	70	31.75
F2						1			1	1	2	79	35.83
F3							1	1	1		2	69	31.30
Stage 2	3	2	0	0		1	1	1	2	2	6	2508	1137.61

Table 9 - Payload Stage 2

Nominal payload: 1183.4Kg – 2609lb
The added masses is 45.8Kg – 101lbs lighter than expected.

Total nominal mass of Stage 2: 2913.9Kg – 6424lb
Error on the nominal overall mass of stage 2: 45.8/2913.9=1.57%

Summary:

	Plan		% diff from Plan	Mass Diff from Plan
Stage 1	108.86	53.37	-50.98	-55.49
Stage 2	1183.42	1137.61	-3.87	-45.81
Total	1292.28	1190.98		

LLO Unit 1, 2 & 3 Results:

Unit 1

	Plan	Original	3/1/2012	3/9/2012	% Diff from Plan	Mass Diff from Plan
Stage 1	108.86	148.10	19.50	36.29	-66.67	-72.57
Stage 2	1183.42	989.42	1089.07	1096.83	-7.32	-86.59

Unit 2

	Plan	6/12/2012	% diff from Plan	Mass Diff from Plan
Stage 1	108.86	60.06	-44.83	-48.81
Stage 2	1183.42	1071.93	-9.42	-111.49

Unit 3

	Plan	8/13/2012	% diff from Plan	Mass Diff from Plan
Stage 1	108.86	39.46	-63.75	-69.40
Stage 2	1183.42	1161.33	-1.87	-10.66

Unit 4

	Plan	7/18/2012	% diff from Plan	Mass Diff from Plan
Stage 1	108.86	47.31	-56.54	-61.55
Stage 2	1183.42	1155.53	-2.36	-27.90
Total	1292.28	1202.84		

LLO Unit 5 is the third one to use these Silver Plated Eastwood Bolts for the Spring Blades and the second Unit to use the new version of the Angled Spacers for Stage 0-1 Blades, Since the Silver Plating allows a better friction with the Nitronic of the Barrel Nuts, we decided to go back to the initial torque value for these bolts: 110 ft.lbs; we can see the benefits of these two changes especially on Stage 2! See E1300057 for more details.

Previous Units Results:

	Plan	LHO Unit 1	LHO Unit 2	LLO Unit 1	**LLO Unit 2**	**LLO Unit 3**	**LLO Unit 4**	Avg (6 1st Units)	STD	**LLO Unit 5**
Stage 1	108.86	35.6	58.6	36.29	**60.06**	**39.46**	**47.31**	46.22	10.97	**53.37**
Stage 2	1183.42	1082.4	1059.5	1096.83	**1071.93**	**1161.33**	**1155.53**	1104.59	35.64	**1137.61**
Stage 1	103.97	-33.30	9.80	-32.00	12.54	-26.06	-11.35	-13.40	% of Diff/LLO Unit 5	
Stage 2	4.03	-4.85	-6.87	-3.58	-5.77	2.09	1.58	-2.90		

The results we have on this last Unit confirms what we thought for LLO Unit 4: the new angled spacers for the Stage 0-1 Blades: we have a slightly better mass budget on Stage 1 and almost no

changes on Stage 2. The mass budget on Stage 1 is still very light compared to the original plan, but if we compare it with the Previous Units built at LHO & LLO, we can see that this Unit is in the general tendency:

- Stage 2 Mass Budget is very close to the Plan built to date: about 2% difference.
- Stage 1 Mass Budget is in the general tendency of the 6 first previous Units.

Overall (Stage 1 & Stage 2), this Unit is one of the closest one to the theoretical Mass Plan ever built!

In conclusion, the BSC-ISI seems to benefit a lot from these new bolts and a little bit from the new design of the Angled Spacers.

Note: This Unit is the first one built with the D1100570-V2 Stage 0-1 Angled Blade Spacers. This Version 2 has a slightly different launching angle than the first Version and that brings us closer to the overall Plan but Stage 1 is still far from what we want ~ 49% away.

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

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

Measurements using the CPS sensors when the stages are locked and unlocked have been done Step III.2.

Note: On this Unit, first leveled both stages without centering the lockers horizontally. Then in order to record the initial twist, we put the pins back to lock both stages in their nominal position, zeroed the dial indicators and removed the pins. Here are the values for the initial twist of LLO last Unit:

Dial indicators H (mil)
-7
-8
-19

After adjustments:

Dial indicators V (mil)	Dial indicators H (mil)
-0.75	1
0	0
1	-1

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

- ***Step 12 – Cables inventory – E1100822***

The final Class A cables have been used for the testing of this Unit.

	Type of Cable	Corner 1	Corner 2	Corner 3
St 0-1 V Actuators	Pigtail	D1100150 – S1107091	D1100151 – S1107203	D1100151 – S1107174
	Extension	D1100148 – S1107056	D1100148 – S1106969	D1100148 – S1106958
St 0-1 H Actuators	Pigtail	D1100150 – S1107124	D1100151 – S1107214	D1100151 – S1107157
	Extension	D1100148 – S1106905	D1100148 – S1106906	D1100148 – S1106913
St 1-2 V Actuators	Pigtail	D1100150 – S1107128	D1100150 – S1107083	D1100151 – S1107180
	Extension	D1100148 – S1106944	D1100148 – S1106953	D1100148 – S1106971
St 1-2 H Actuators	Pigtail	D1100150 – S1107070	D1100150 – S1107068	D1100151 – S1107186
	Extension	D1100148 – S1106956	D1100148 – S1106954	D1100148 – S1106949
L4C	Pigtail	D1100154 – S1107331	D1100154 – S1107343	D1100155 – S1107399
	Extension	D1100152 – S1107239	D1100153 – S1104566	D1100153 – S1105206
GS-13	Pigtail	D1100154 – S1107342	D1100155 – S1107409	D1100155 – S1107387
	Extension	D1100153 – S1104568	D1100153 – S1107278	D1100153 – S1107282
T240		D1100152 – S1107254	D1100152 – S1107231	D1100153 – S1104570

Note: Some changes might occur after the install.

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

- ***Step 13 - Cable routing***

The final Class A cables have been used for the testing of this Unit.
The cabling has been done following E1101027 aLIGO BSC-ISI Cable Routing Manual.

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

III. Tests to perform after assembly

- ***Step 1- Geophones pressure readout***

	Pressure (counts)		
Sensors	**Corner 1**	**Corner 2**	**Corner 3**
ST1-L4C-P	99.63	99.72	99.79
ST1-L4C-D	-0.03	0.26	0.30
ST1-GS13-P	100.19	77.67	76.68
ST1-GS13-D	0.99	0.00	0.98
ST1-T240-P	154.44	154.81	154.65

Nominal Value for the Pressure Readout: 100 counts

Test mitigation:

On LLO BSC Unit 1, L4C-P in Corner 1 was giving strange signal, but it didn't come from the pressure sensor, it was coming from the interface SN S1106357. This interface was replaced with S1102219.

Replacing the Interface Chassis of Corner 1 fixed the issue we had about the pressure sensor Readout on the GS-13. This issue is still here on Corner 2 & 3, but we know the problem comes from the interfaces used for these Corners. That explains why we have reading ~77 counts on these GS-13's.

The Pressure value on the Trillium is ~150 counts, which is not realistic. We've always had that issue (probably due to the Interfaces in the HighBay) but we know that a pressure readout of ~150 counts means that the pressure sensor works (otherwise the pressure readout is 30 counts!).

So we know we have good pressure sensors in this Unit's pods.

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

- ***Step 2- Set up sensors gap – Locked vs unlocked position***

During this step, sensors gap are adjusted. This step considers that the lockers have been finely setup during assembly.

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	Table locked		Table unlocked		Difference locked - unlocked	
Sensors	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**Std deviation**	**Offset (Mean)**	**mil**
ST1 - H1	31.1	16.8	-311.5	77.7	-342.6	-0.4
ST1 - H2	56.6	16.1	-258.4	81.2	-315.0	-0.4
ST1 - H3	116.3	14.1	-416.6	90.1	-532.9	-0.6
ST1 - V1	215.5	20.0	414.8	268.5	199.3	0.2
ST1 - V2	-210.1	12.9	281.3	293.0	491.4	0.6
ST1 - V3	215.1	19.7	96.5	223.7	-118.6	-0.1
ST2 - H1	165.6	32.3	550.8	182.9	385.2	0.1
ST2 - H2	-157.8	43.9	-1114.9	79.5	-957.1	-0.3
ST2 - H3	-674.3	20.2	-507.9	186.4	166.4	0.0
ST2 - V1	287.5	42.6	-3113.9	779.1	-3401.4	-1.0
ST2 - V2	185.6	39.8	-433.9	797.0	-619.5	-0.2
ST2 - V3	-62.9	33.9	-2189.1	659.0	-2126.2	-0.6

Table 10 - Capacitive position sensors readout after gap set-up

Acceptance criteria:

- In the locked position, all mean values must be lower than 400 counts for stage 1 CPS and 1600 counts for stage 2 CPS (a bit less than .0005").
- In the locked position, all standard deviations below 25 counts for stage 1, 100 counts for stage 2
- Absolute values of the difference between the unlocked and the locked table must be below:
  Stage 1
    - 1600 cts for horizontal sensors (~0.002")
    - 1600 cts for vertical sensors (~0.002")

  Stage 2
    - 6500 cts for horizontal sensors (~0.002")
    - 6500 cts for vertical sensors (~0.002")
- Considering the acceptance criteria of step 2, all mean values must be lower than
  Stage 1
    - 2000 cts for horizontal sensors (~0.0025")
    - 2000 cts for vertical sensors (~0.0025")

  Stage 2
    - 8000 cts for horizontal sensors (~0.0025")
    - 8000 cts for vertical sensors (~0.0025")

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

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

Test Failure mitigation:
This test was not performed. The sensor gaps have not been measured. These sensors have already been tested at LASTI. Moreover, risks of scratching the target are so high that we preferred not performing this test. In the future, this test will be removed from the testing procedure.

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

Step 4- Performance of the limiters

Step 4.1 - Test Nº1 - Push "in the general coordinates Z/RZ"

	CPS read out		Calculated after calibration	
Sensors	**"-Z" (Counts)**	**"+Z" (Counts)**	**"-Z" (mil)**	**"+Z" (mil)**
ST1 - V1 - ST2 LCK	-17453.0	13800	-20.8	16.4
ST1 - V2 - ST2 LCK	-16587.0	16841	-19.7	20.0
ST1 - V3 - ST2 LCK	-16677.0	12436	-19.9	14.8
ST2 - V1 - ST1 LCK	-32768.0	32707.0	-9.8	9.7
ST2 - V2 - ST1 LCK	-32768.0	32767.0	-9.8	9.8
ST2 - V3 - ST1 LCK	-32768.0	32741.0	-9.8	9.7

	CPS read out		Calculated after calibration	
Sensors	**"-RZ" (Counts)**	**"+RZ" (Counts)**	**"-RZ" (mil)**	**"+RZ" (mil)**
ST1 - H1 - ST2 LCK	16155.0	-15758.0	19.2	-18.8
ST1 - H2 - ST2 LCK	15223.0	-15426.0	18.1	-18.4
ST1 - H3 - ST2 LCK	15600.0	-15178.0	18.6	-18.1
ST2 - H1 - ST1 LCK	-28097.0	24450.0	-8.4	7.3
ST2 - H2 - ST1 LCK	-26797.0	27865.0	-8.0	8.3
ST2 - H3 - ST1 LCK	-25833.0	27754.0	-7.7	8.3

Note: This test can be tricky to do because all three pushers need to push perfectly horizontally or vertically without influencing the other direction (vertical or horizontal). Even if this test doesn't meet the requirements, the next test "Push locally" results show us that the system moves freely.

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

- ***Step 4.2 - Test Nº2 – Push "locally"***

Sensors	Push in positive direction	Push in negative direction	Mil	Mil	Railing	Actuator Gap Check
ST1 - H1	-19747	19750	-24	24		OK
ST1 - H2	-19481	19643	-23	23		OK
ST1 - H3	-16600	20603	-20	25		OK
ST1 - V1	22371	-24046	27	-29		OK
ST1 - V2	19104	-25246	23	-30		OK
ST1 - V3	20902	-24756	25	-29		OK
ST2 - H1	32767	-32768	10	-10	X	OK
ST2 - H2	32767	-32768	10	-10	X	OK
ST2 - H3	32767	-32768	10	-10	X	OK
ST2 - V1	32767	-32768	10	-10	X	OK
ST2 - V2	32767	-32768	10	-10	X	OK
ST2 - V3	32767	-32768	10	-10	X	OK

Table 11 - Stages range of motion – "Push locally"

Acceptance criteria:

- The vertical sensor readout must be positive when the optical table is pushed in the +Z direction
- The horizontal sensor readout on Stage 2 must be positive when the optic table is pushed in the +RZ direction
- **Step 4.2**
  - Absolutes value of all estimated motions must be higher than 15000counts for stage 1 (~0.018")
  - Absolutes value of all estimated motions must be higher than 32000counts for stage 2 (~0.010")

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

- ***Step 5 - Sensors Powespectra***

The geophones powerspectra have been measured and can be found in the SVN:

/seismic/BSC-ISI/X2/BSC5/Data/Figures/Spectra/Undamped/

- LLO_ISI_BSC5_Powerspectra_ct_ST1_Unlocked_ST2_Unlocked_2013_04_02.fig
- LLO_ISI_BSC5_Powerspectra_ct_ST1_Locked_ST2_Locked_2013_04_02.fig
- LLO_ISI_BSC5_Powerspectra_ct_ST1_Locked_ST2_Unlocked_2013_04_02.fig
- LLO_ISI_BSC5_Powerspectra_ct_ST1_Unlocked_ST2_Locked_2013_04_02.fig
- LLO_ISI_BSC5_Tilted_ASD_CT_LOC_ST1_L4C_2013_04_02.fig
- LLO_ISI_BSC5_Tilted_ASD_m_LOC_ST1_L4C_2013_04_02.fig
- LLO_ISI_BSC5_Tilted_ASD_CT_LOC_ST2_GS13_2013_04_02.fig
- LLO_ISI_BSC5_Tilted_ASD_m_LOC_ST2_GS13_2013_04_02.fig

/seismic/BSC-ISI/X2/BSC5/Data/Spectra/Undamped

- LLO_ISI_BSC5_ASD_m_LOC_CPS_T240_L4C_GS13_2013_04_02_211656.mat
- LLO_ISI_BSC5_ASD_m_L4C_GS13_Stage_Tilted_2013_04_02.mat

Stage locked – unlocked

The powerspectra are measured in four different configurations:

- Stage 1 locked – Stage 2 locked
- Stage 1 unlocked – Stage 2 locked
- Stage 1 locked – Stage 2 unlocked
- Stage 1 unlocked – Stage 2 unlocked

The series of plots below present calibrated powerspectra:

- The de-whitening filters are suppressed

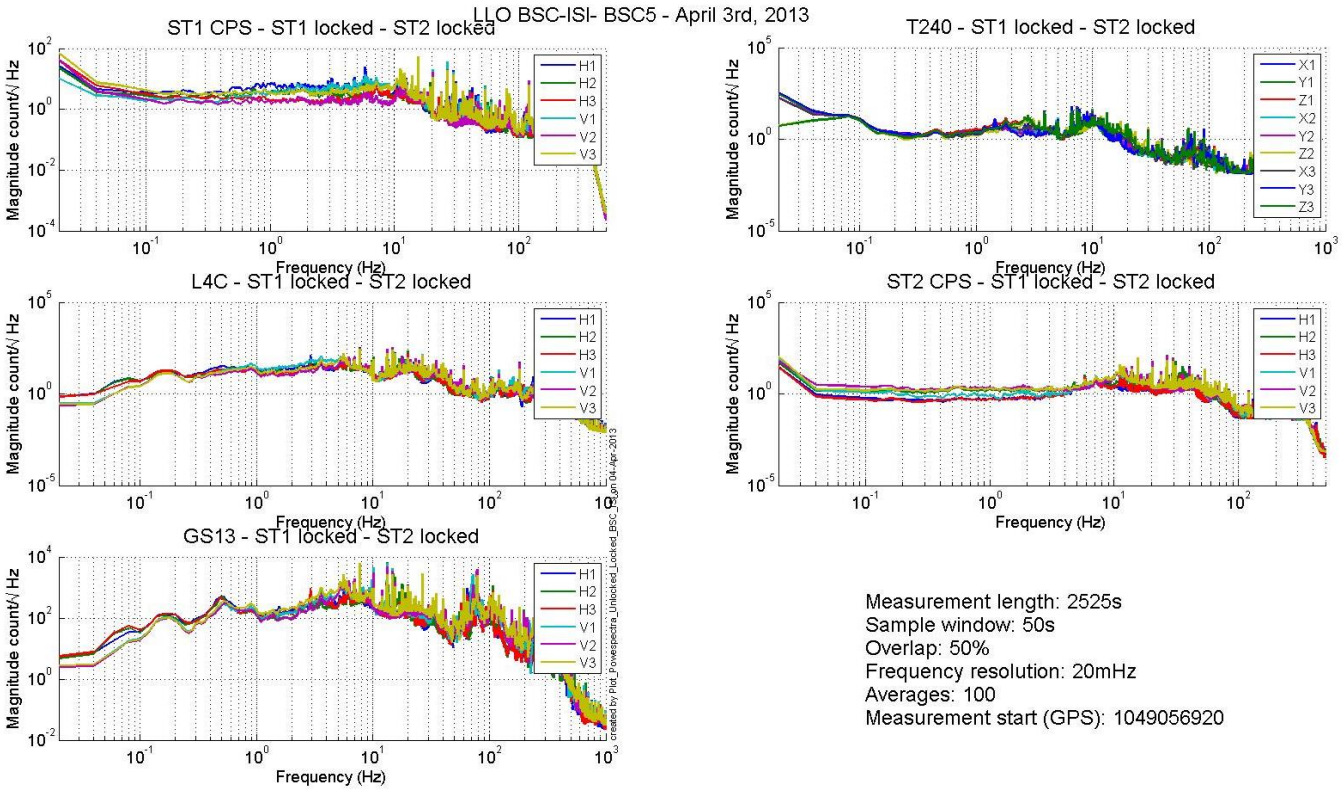


Figure 10: Spectra Stage 1 Locked Stage 2 Locked

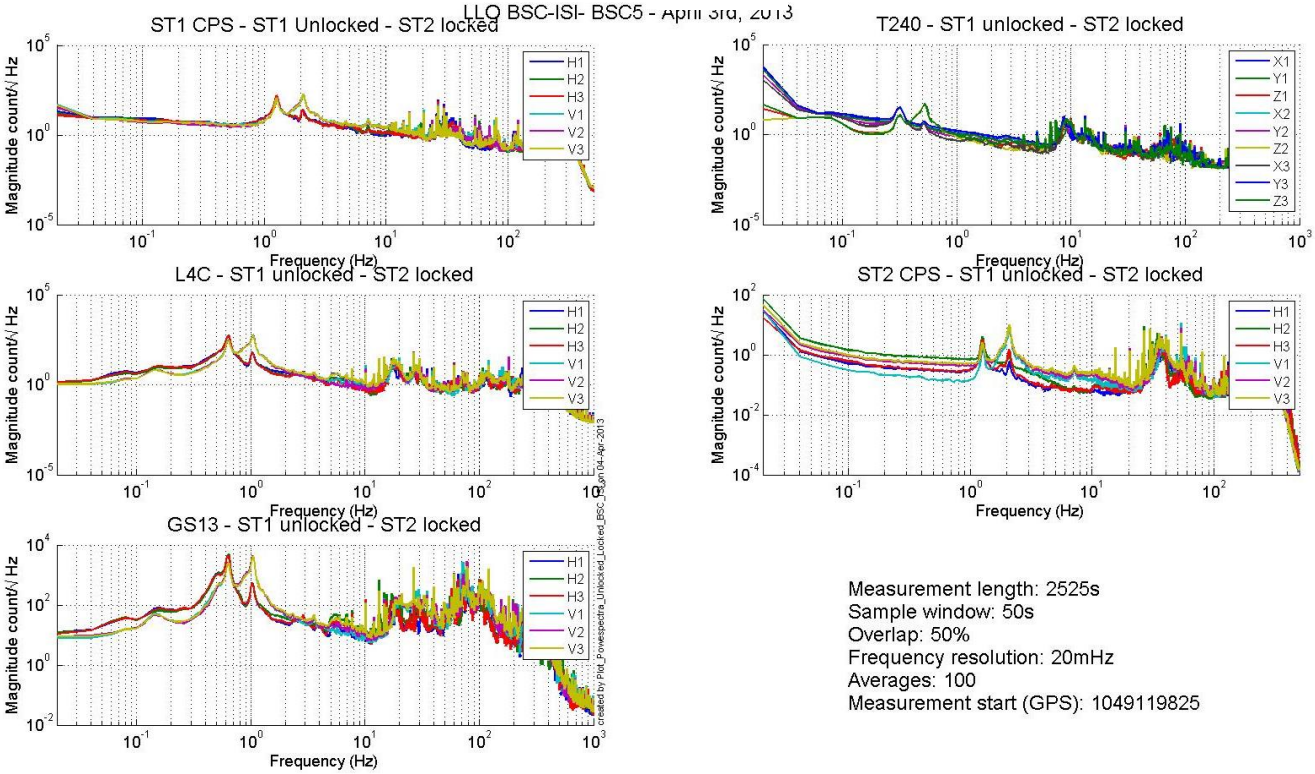


Figure 11: Spectra Stage 1 Unlocked Stage 2 Locked

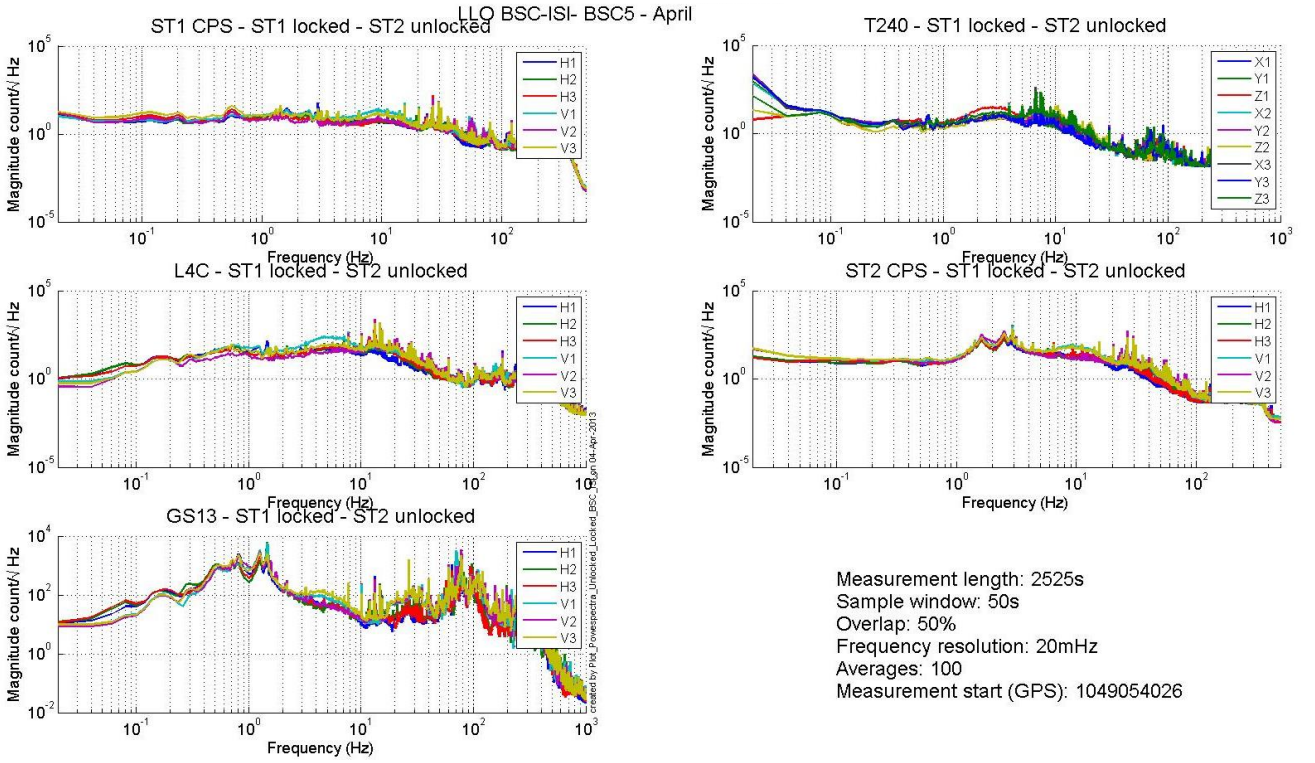


Figure 12: Spectra Stage 1 Locked Stage 2 Unlocked

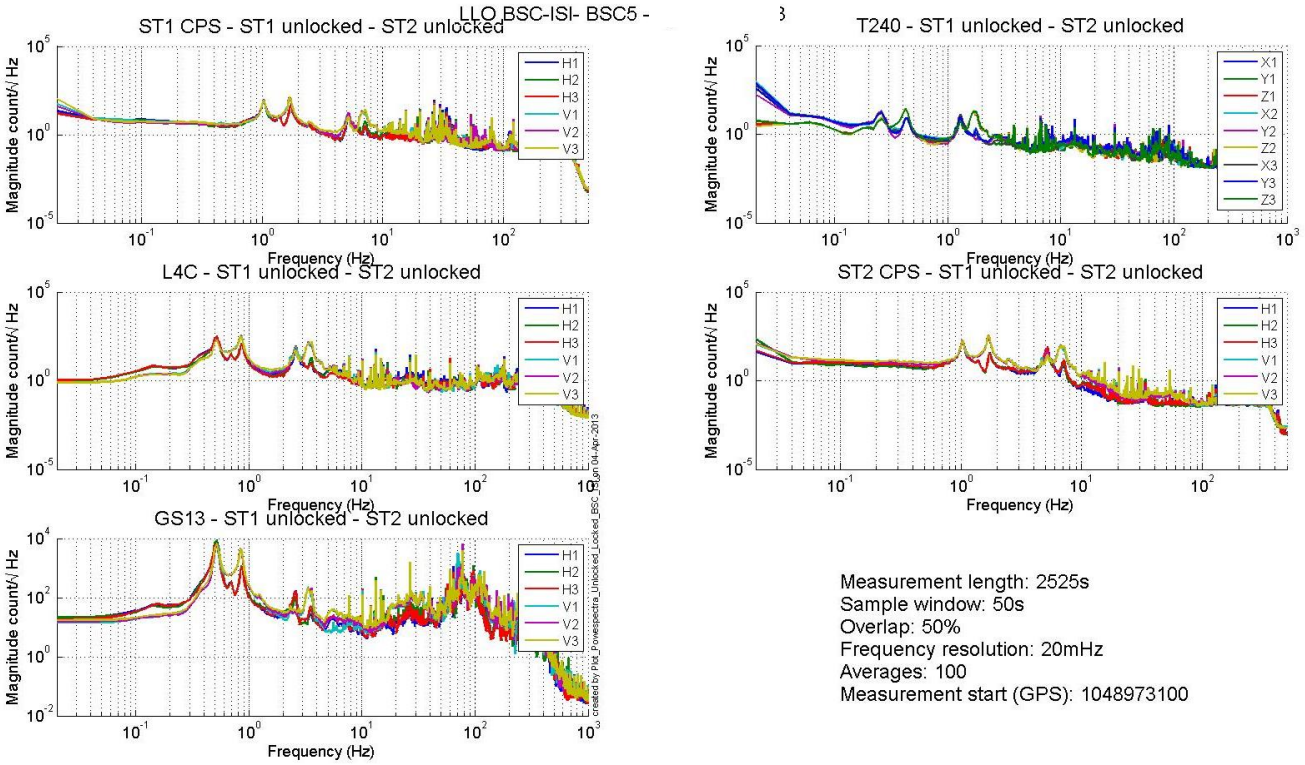


Figure 13: Spectra Stage 1 Unlocked Stage 2 Unlocked

Stage Tilted

The powerspectra are measured when the ISI is unlocked a mass is placed on stage 2 to tilt Stage 1 and Stage 2.

The six configurations are the following in six different configurations:

- Mass placed in the actuator pocket at corner 1
- Mass placed in the pocket under the blade 0-1 at corner 1
- Mass placed in the actuator pocket at corner 2
- Mass placed in the pocket under the blade 0-1 at corner 2
- Mass placed in the actuator pocket at corner 3
- Mass placed in the pocket under the blade 0-1 at corner 3

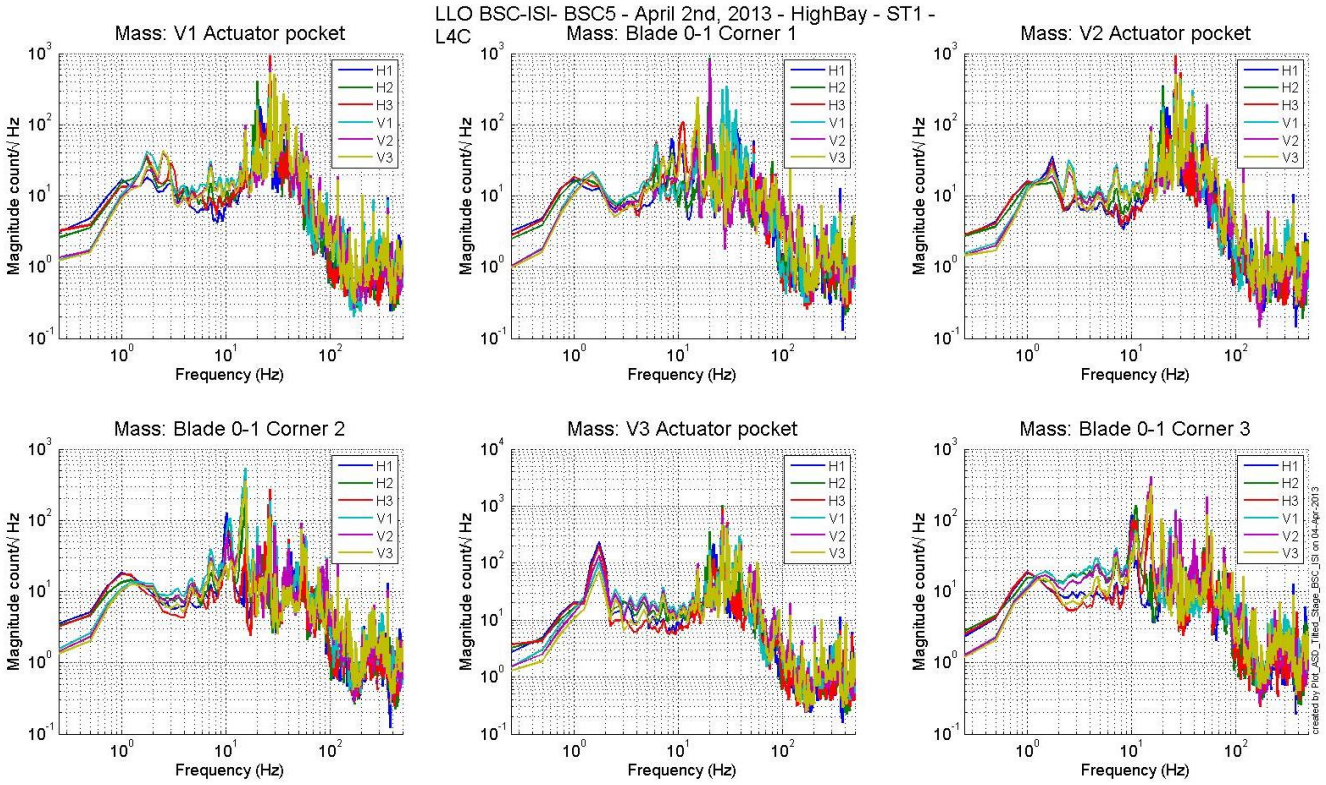


Figure 14 - ST1 L4C – Tilted

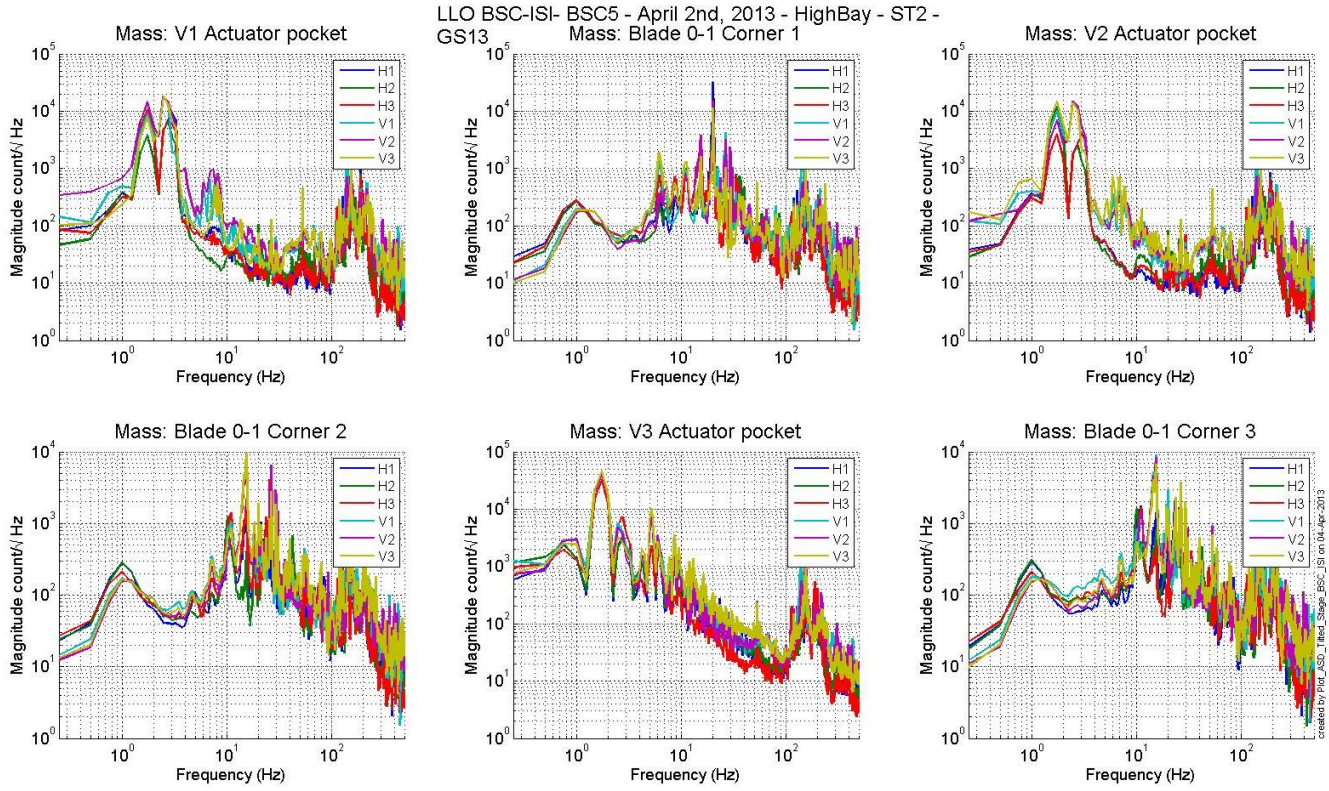


Figure 15 - ST1 GS13 – Tilted

- ***Step 6 - Coil Driver, cabling and resistance check***

Resistances of the couple actuator + cables are reported in the table below:

Actuator	Coil driver name	Resistance (Ω)
ST1 H1	Coil1 Coarse 1	6.7
ST2 H1	Coil 1 Fine 1	10.5
ST2 V1	Coil 1 Fine 2	10.4
ST1 V1	Coil 1 Coarse 2	6.8
ST1 H2	Coil 2 Coarse 1	6.8
ST2 H2	Coil 2 Fine 1	10.9
ST2 V2	Coil 2 Fine 2	10.6
ST1 V2	Coil 2 Coarse 2	6.9
ST1 H3	Coil 3 Coarse 1	6.7
ST2 H3	Coil 3 Fine 1	10.9
ST2 V3	Coil 3 Fine 2	10.5
ST1 V3	Coil 3 Coarse 2	6.7

Acceptance criteria:

- For the actuators of stage 1, the measured resistance between the middle pin and one side pin must be 6.3 +/-0.5 ohms
- For the actuators of stage 2, the measured resistance between the middle pin and one side pin must be 10.3 +/-0.5 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 binary input bit must be in the upper state.

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

- ***Step 7- Actuators Sign and range of motion (Local drive)***
  - ***Step 7.1 - Actuators sign***

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

  - ***Step 7.2 - Range of motion - Local drive***

In this step, range of motion of the two stages is checked when applying a local drive (30000 counts) on actuators.

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1	-16238	-117	16758	32996	39
ST1 - H2	-16623	-317	16117	32740	39
ST1 - H3	-15710	-519	16904	32615	39
ST1 - V1	-15289	-325	14650	29939	36
ST1 - V2	-14695	146	15041	29736	35
ST1 - V3	-14716	42	14995	29711	35
ST2 - H1	-9491	657	10835	20326	6
ST2 - H2	-11273	-1544	8158	19432	6
ST2 - H3	-7144	2888	12899	20043	6
ST2 - V1	-15255	-2711	9820	25074	7
ST2 - V2	-13216	-814	11533	24749	7
ST2 - V3	-12588	-245	12066	24654	7

Table 12 - Range of motion - Local drive

Acceptance criteria:

- Amplitude must be at least 32000 counts (+/-0.02") for H Stage 1 CPS
- Amplitude must be at least 29000 counts (~0.010") for V Stage 1 CPS
- Amplitude must be at least 19000 counts (+/-0.02") for H Stage 2 CPS
- Amplitude must be at least 23000 counts (~0.010") for V Stage 2 CPS
- Signs of actuators drive and sensors read out have to be the same

Note: The motion of the platform can be computed. For a 30000 counts drive in the +Z direction, the platform should move by 12.6 mil on Stage 1 and 3.6mil on Stage 2.

In the Cartesian basis, the platform should move (calculation) by:

Stage 1 - Platform move for 32K counts drive: 12.63 mil

Stage 2 - Platform move for 32K counts drive: 3.59 mil

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

- ***Step 8 - Vertical Sensor Calibration***

This test is inaccurate due to the important hysteresis introduced by the dial indicators. Moreover, the sensors calibrations have been checked at LASTI. This test has not been performed on LLO Unit 4.

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

- ***Step 9 - Vertical Spring Constant***

This test is realized by loading the ISI when one stage is locked and using the capacitive position sensors as reference.

The stiffness measurements of the spring are reported in the tables below. The nominal blade stiffness are:

- Stage 1: 1241lb/in
- Stage 2: 1465lb/in

Blade Stage 0-1

Stage 2 Locked & Stage 1 Unlocked. Stage 1 is loaded with 3 x 10Kg masses and the measurements are repeated three times (by rotating the masses).

	No load	Load 15 Kg	Load 30Kg	Diff 1	Diff 2
V1	403.07	0.00	-14670.00	-403.07	-15073.07
V2	211.41	0.00	-14986.00	-211.41	-15197.41
V3	-48.78	0.00	-15185.67	48.78	-15136.88

-15135.78789	count
-18.01879511	mil
-1222.41424	lb/in
1.497643867	**%**

The blades from stage 0 to stage 1 are too soft by 1.50%.

Blade Stage 1-2

Stage 1 Locked & Stage 2 Unlocked. Stage 2 is loaded with 3 x 5Kg masses and the measurements are repeated three times (by rotating the masses).

	No load	Load	Diff
V1	-3054.70	-27800.33	24745.63
V2	-302.09	-25784.00	25481.91
V3	-1960.00	-27803.00	25843.00

25356.85	count
7.55	mil
1446.600265	lb/in
1.255954628	%

The blades from stage 1 to stage 2 are too soft by 1.26%.

Note:

A dirty assembly was built at LASTI for fit-check and testing purpose before the first assembly at LHO & LLO. During balancing, the total added mass on top of stage 2 to simulate the payload was far from nominal. Investigations on the blades stiffness showed an extra softness of the blade of both stages. But the mass deduction to compensate this extra softness didn't explain the difference with the nominal payload. In order to be closer to the nominal payload, the angles of the blade spacers were corrected (correction equivalent to +253lb on stage 0-1 blade and +507lb on stage 1-2 blade). These discrepancies between the initial design and assembly can be explained by:

- Inaccuracy in Solidworks estimation. It might underestimate masses of actual components (metal parts, hardware, instruments...)
- Measurement errors of the blade stiffness
- Machining errors (launch angles, assembly stack up...)
- Extra compliance due to the stages deformation

After these first results, a second version of D1100570 Stage 0-1 Angled Blades Spacer has been issued in order to 25 lbs per corner to the ISI (total correction of 253+75=328 lbs on Stage 0-1 and 507 lbs on Stage 1-2).

This is the fourth Unit built at LLO, but the first one using the new version of the Angled Spacers for the Stage 0-1 Blades and the second one to use Silver Plated Eastwood SHCS to clamp the Spring Blade which allows a better friction coefficient and thus for the same torque value more clamping force than with the previous Stainless Eastwood Bolts. Since our first Unit, we also use oversized .5015" dowel pins, with the Blade brought as far back as possible to guarantee repeatability.

The very good results on the Mass Budget and on this Vertical Spring Constant Test show us that switching from the Stainless to the Silver Plated Bolts was the right decision, and that the new version of the angled spacers makes the mass budget a little bit better on Stage 1!

Facts:

- Nominal load on Stage 0-1 blades is 8240 lb (per initial design estimation)
- -1.50% of 8240 lb is -123.6 lbs.
- +328 lb are compensated per ST1 - launch angle correction (E1100284, line 9 & D1100570-V2)
- So we should be at +328-123.6= 204.4 lb over nominal (93kg).

But in reality, we are 110 kg too light, so we have 110 + 93 = 213 kg unexplained!

But we have to keep in mind that every blade is different (see E1300057).

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

- ***Step 10 - Static Testing (Tests in the local basis)***

The table below shows the main and the cross-coupling when the actuators are driven in the local basis:

The static tests results are reported in the SVN at :
/seismic/BSC-ISI/X2/BSC5/Data/Static_Tests/

- LLO_ISI_BSC5_Offset_Local_Drive_20130403.mat

Actuators \ Sensors	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - H1	4288.8	1750.4	1776.2	16.3	-1.8	-14.1
ST1 - H2	1730.8	4340.5	1749.8	-10.4	60.5	-4.8
ST1 - H3	1734.6	1742.1	4341.5	1.4	4.1	8.8
ST1 - V1	61.2	-172.9	100.1	3512.7	-640.3	-641.6
ST1 - V2	57.1	3.9	-180.7	-620.1	3470.9	-637.2
ST1 - V3	-169.1	118.8	76.0	-656.3	-590.4	3498.2

Table 13 - Static test - Local to local - Stage 1

Actuators \ Sensors	ST1 - H1 (min, max)		ST1 - H2 (min, max)		ST1 - H3 (min, max)		ST1 - V1 (min, max)		ST1 - V2 (min, max)		ST1 - V3 (min, max)	
ST1 - H1	4327.1	4462.0	1716.0	1780.0	1744.7	1794.0	-15.0	29.0	-23.2	-7.0	-9.3	28.7
ST1 - H2	1715.0	1770.8	4224.0	4393.3	1705.0	1786.2	-15.5	8.5	-22.5	46.2	-17.3	7.0
ST1 - H3	1729.6	1748.5	1716.0	1759.7	4246.0	4363.1	-17.8	2.4	-5.3	6.1	-1.7	65.4
ST1 - V1	33.3	86.4	-184.6	-144.4	75.4	119.1	3481.0	3587.0	-665.0	-616.5	-650.4	-588.0
ST1 - V2	91.0	132.0	15.3	87.0	-178.3	-135.0	-631.0	-597.3	3385.0	3560.3	-695.8	-615.0
ST1 - V3	-159.1	-102.0	93.0	128.0	31.0	79.1	-664.1	-591.0	-636.0	-570.0	3347.0	3803.9

Table 14: Static Test – Local to Local – Stage 1 Results (min & max) from the previous BSC Units

Actuators \ Sensors	ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
ST2 - H1	2403.2	377.8	368.6	39.2	12.5	40.8
ST2 - H2	365.5	2293.5	386.0	-11.5	-61.2	28.5
ST2 - H3	393.4	372.4	2374.7	-8.6	8.1	39.1
ST2 - V1	119.7	136.6	-189.4	2997.9	302.3	40.7
ST2 - V2	-174.4	86.3	133.6	-0.3	2865.6	287.8
ST2 - V3	152.0	-211.6	88.0	314.3	-47.4	2926.1

Table 15 - Static test - Local to local - Stage 2

Actuators	Sensors											
	ST2 – H1 (min, max)		ST2 - H2 (min, max)		ST2 - H3 (min, max)		ST2 - V1 (min, max)		ST2 - V2 (min, max)		ST2 - V3 (min, max)	
ST1 - H1	2316.0	2439.3	349.5	383.5	337.0	371.0	-33.6	18.0	-77.9	50.1	-64.9	36.0
ST1 - H2	324.0	366.4	2328.3	2454.7	336.3	373.0	-65.8	27.0	-85.9	62.3	-81.4	51.4
ST1 - H3	311.0	406.5	341.5	411.4	2313.9	2390.7	-77.1	31.0	-79.7	59.4	-134.8	53.9
ST1 - V1	65.0	107.4	107.3	142.3	-220.0	-171.1	2769.6	3018.1	213.4	354.1	-106.4	59.5
ST1 - V2	-244.0	-153.0	50.3	180.9	94.0	134.8	-161.4	15.1	2599.9	2968.3	225.5	400.9
ST1 - V3	78.5	163.2	-229.2	-152.6	41.0	97.0	250.7	363.0	-140.0	-27.4	2707.1	2960.0

Table 16: Static Test – Local to Local – Stage 2 Results (min & max) from the previous BSC Units

Acceptance criteria:

- Main couplings readout must be positive
- Comparison with the reference tables:
  - Main coupling differences mustn't exceed 200 counts
  - Cross coupling differences mustn't exceed 50 counts

Reference tables for acceptance criteria:

Actuators \ Sensors	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - H1	4380	1750	1750	0	0	0
ST1 - H2	1750	4380	1750	0	0	0
ST1 - H3	1750	1750	4380	0	0	0
ST1 - V1	50	-170	90	3500	-650	-650
ST1 - V2	90	50	-170	-650	3500	-650
ST1 - V3	-170	90	50	-650	-601	3500

Table - Main couplings – Static – Stage 1

Actuators \ Sensors	ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
ST2 - H1	2401	360	360	0	0	0
ST2 - H2	360	2401	360	0	0	0
ST2 - H3	360	360	2377	0	0	0
ST2 - V1	80	130	-200	3050	330	0
ST2 - V2	-200	80	130	0	2950	330
ST2 - V3	130	-200	80	330	0	2950

Table - Main couplings – Static – Stage 2

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

- ***Step 11- Static Testing - In the general coordinate basis (Static test - CPS)***
  - ***Step 11.1 – Change of basis matrices from Cartesian to Local***

The table below shows the main and the cross-coupling when the actuators are driven in the Cartesian basis:

The static tests results are reported in the SVN at :
/seismic/BSC-ISI/X2/BSC4/Data/Static_Tests/

- LLO_ISI_BSC4_Offset_Cartesian_Drive_20130114.mat

Actuators	Sensors					
	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - X	1711	-851	-841	26	-26	-14
ST1 - Y	-1	1521	-1483	-12	20	-28
ST1 - Z	-5	-21	0	728	732	726
ST1 - RX	-28	145	-176	-2917	2407	446
ST1 - RY	-183	141	121	-1207	-1915	3076
ST1 - RZ	3151	3193	3200	-4	-5	4

Table 17 - Static test cartesian drive – Cartesian to local – Stage 1

Actuators	Sensors											
	ST1 - H1 (min, max)		ST1 - H2 (min, max)		ST1 - H3 (min, max)		ST1 - V1 (min, max)		ST1 - V2 (min, max)		ST1 - V3 (min, max)	
ST1 - X	1716.3	1803.0	-875.0	-839.0	-862.0	-812.0	-26.0	23.0	-17.0	0.4	-26.1	32.8
ST1 - Y	-32.0	22.0	1493.0	1537.7	-1505.1	-1448.5	-15.6	23.6	-18.0	55.2	-46.6	-9.0
ST1 - Z	-33.0	8.0	-19.0	0.6	-27.5	16.0	728.5	772.0	709.0	758.3	711.0	824.0
ST1 - RX	-31.0	40.0	126.0	189.0	-168.3	-137.0	-2937.0	-2877.0	2408.0	2470.0	413.8	486.0
ST1 - RY	-196.5	-151.8	77.0	112.3	64.2	120.0	-1185.9	-1117.0	-1955.6	-1871.0	2959.0	3310.0
ST1 - RZ	3154.2	3230.0	3124.0	3229.0	3146.5	3213.3	-20.5	33.0	-32.9	23.0	-27.0	43.6

Table 18 - Static test cartesian drive – Cartesian to local – Stage 1 Results (min & max) from the previous BSC Units

Actuators \ Sensors	ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
ST2 - X	675	-1285	665	35	108	53
ST2 - Y	1167	22	-1145	-8	-20	-60
ST2 - Z	-10	16	-2	1052	1155	1023
ST2 - RX	-286	11	273	-2481	2596	-56
ST2 - RY	165	-345	151	-1503	-1336	2894
ST2 - RZ	1761	1718	1764	3	61	-5

Table 19 - Static test cartesian drive – Cartesian to local – Stage 2

Actuators \ Sensors	ST2 - H1 (min, max)		ST2 - H2 (min, max)		ST2 - H3 (min, max)		ST2 – V1 (min, max)		ST2 - V2 (min, max)		ST2 - V3 (min, max)	
ST2 - X	665.0	716.0	-1389.8	-1312.0	653.0	680.5	-63.0	42.6	-79.0	16.0	-77.7	44.0
ST2 - Y	1144.0	1198.0	-52.5	30.3	-1193.9	-1137.0	-89.0	51.4	-136.0	10.0	-103.0	53.0
ST2 - Z	-3.0	26.9	-15.5	16.1	-33.0	21.0	1017.9	1133.0	939.0	1135.0	929.0	1104.4
ST2 - RX	-312.0	-249.6	-25.0	45.5	243.5	288.0	-2572.0	-2362.0	2289.0	2574.0	-153.7	-49.0
ST2 - RY	116.6	200.0	-405.4	-266.0	116.0	189.0	-1595.0	-1384.0	-1513.4	-1123.3	2644.0	2972.0
ST2 - RZ	1738.0	1797.0	1715.0	1822.0	1728.0	1792.0	-101.0	46.0	-122.0	8.0	-66.0	47.5

Table 20 - Static test cartesian drive – Cartesian to local – Stage 2 Results (min & max) from the previous BSC Units

Reference table static test Cartesian to local:

Actuators \ Sensors	ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
ST1 - X	1800	-820	-820	0	0	0
ST1 - Y	0	1500	-1500	0	0	0
ST1 - Z	0	0	0	772	750	700
ST1 - RX	0	160	-160	-2950	2450	450
ST1 - RY	-200	110	70	-1150	-2000	3050
ST1 - RZ	3200	3200	3200	0	0	0

Table 21 - Reference table - Cartesian to Local - Stage 1

Actuators \ Sensors	ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
ST2 - X	700	-1350	650	0	0	0
ST2 - Y	1200	0	-1150	0	0	0
ST2 - Z	0	0	0	1100	1100	1100
ST2 - RX	-300	0	300	-2500	2500	-50
ST2 - RY	200	-300	200	-1500	-1400	3000
ST2 - RZ	1800	1800	1800	40	40	40

Table 22 - Reference table - Cartesian to Local - Stage 2

Acceptance criteria:

- Comparison with the reference tables:
  - Differences mustn't exceed 100 counts

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

○ *Step 11.2 – Base change matrices from Cartesian to Cartesian*

The static tests results are reported in the SVN at :
/seismic/BSC-ISI/X2/Data/BSC4/Static_Tests/

- LLO_ISI_BSC4_Offset_Cartesian_Drive_20130114.mat

Actuators \ Sensors	ST1 - X	ST1 - Y	ST1 - Z	ST1 - RX	ST1 - RY	ST1 - RZ
ST1 - X	1710	-6	-20	-25	2	2
ST1 - Y	4	1730	-11	20	-10	7
ST1 - Z	7	-19	732	-19	1	-7
ST1 - RX	2	351	-27	3000	14	-18
ST1 - RY	-369	7	-17	8	3004	28
ST1 - RZ	-18	-8	-12	1	-2	3307

Table 23 - Static Test - Cartesian to Cartesian – Stage 1

Actuators \ Sensors	ST1 - X (min, max)		ST1 - Y (min, max)		ST1 - Z (min, max)		ST1 - RX (min, max)		ST1 - RY (min, max)		ST1 - RZ (min, max)	
ST1 - X	1714.8	1772.1	-13.0	9.0	-11.1	10.9	-13.5	6.0	-20.6	9.6	-3.0	59.0
ST1 - Y	-29.4	8.7	1720.0	1747.0	-20.9	11.0	-10.0	31.2	-54.3	3.0	-4.0	43.3
ST1 - Z	-15.0	10.2	-8.7	17.0	729.0	775.0	-25.0	15.0	-27.0	58.0	-14.9	0.0
ST1 - RX	-16.2	40.8	351.4	380.0	-25.0	7.0	2985.0	3058.0	-23.5	19.0	-18.0	29.0
ST1 - RY	-387.0	-342.0	-5.6	16.0	-19.7	67.0	-9.0	25.0	2901.0	3188.0	-5.1	13.5
ST1 - RZ	-18.0	24.0	-4.0	23.3	-27.0	16.0	-6.0	19.5	-2.0	20.0	3276.0	3346.1

Table 24 - Static Test - Cartesian to Cartesian – Stage 1 Results (min & max) from the previous BSC Units

Actuators \ Sensors	ST2 - X	ST2 - Y	ST2 - Z	ST2 - RX	ST2 - RY	ST2 - RZ
ST2 - X	1297	10	14	5	30	37
ST2 - Y	-18	1330	1	-7	1	13
ST2 - Z	-10	27	1083	-11	0	1
ST2 - RX	3	-16	59	4246	3	-2
ST2 - RY	15	7	-19	-11	4252	3
ST2 - RZ	26	16	19	2	7	2526

Table 25 - Static Test - Cartesian to Cartesian – Stage 2

Actuators	Sensors											
	ST2 - X (min, max)		ST2 - Y (min, max)		ST2 - Z (min, max)		ST2 - RX (min, max)		ST2 - RY (min, max)		ST2 - RZ (min, max)	
ST2 - X	1313.1	1377.4	-16.2	40.0	-53.4	48.3	-33.0	55.5	-18.6	28.5	-16.0	27.5
ST2 - Y	-14.6	32.0	1331.0	1358.0	-53.4	20.0	-53.0	59.0	-41.6	55.0	-26.2	34.0
ST2 - Z	-6.0	24.9	-17.2	13.0	968.0	1114.0	-91.0	52.7	-73.0	46.5	-18.0	19.7
ST2 - RX	-62.3	21.0	-31.1	4.2	-155.0	23.6	4007.0	4356.2	-105.3	64.0	-18.0	26.2
ST2 - RY	-24.0	40.3	-17.8	30.0	-127.1	56.9	-51.0	241.5	4055.2	4319.0	-39.2	24.0
ST2 - RZ	-14.8	21.0	-7.2	18.0	-71.6	29.0	-39.0	73.9	-28.9	52.0	2509.0	2602.0

Table 26 - Static Test - Cartesian to Cartesian – Stage 2 Results (min & max) from the previous BSC Units

Reference table static test Cartesian to Cartesian:

Actuators	Sensors					
	ST1 - X	ST1 - Y	ST1 - Z	ST1 - RX	ST1 - RY	ST1 - RZ
ST1 - X	1750	0	0	0	0	0
ST1 - Y	0	1750	0	0	0	0
ST1 - Z	0	0	750	0	0	0
ST1 - RX	0	375	0	3000	0	0
ST1 - RY	-375	0	0	0	3000	0
ST1 - RZ	0	0	0	0	0	3300

Actuators	Sensors					
	ST2 - X	ST2 - Y	ST2 - Z	ST2 - RX	ST2 - RY	ST2 - RZ
ST2 - X	1350	10	30	0	25	20
ST2 - Y	-10	1350	20	-25	0	20
ST2 - Z	0	0	1100	-10	-30	20
ST2 - RX	10	-15	20	4300	30	20
ST2 - RY	30	0	30	40	4300	20
ST2 - RZ	0	10	30	-25	-15	2600

Acceptance criteria:

- Main couplings readout must be positive
- Comparison with the reference tables:
  - Main coupling differences mustn't exceed 200 counts
  - Cross coupling differences mustn't exceed 50 counts

Note: We have highlighted in yellow the values that don't satisfy the acceptance criteria. But by comparing these values with the ones from the previous Units built at LHO and LLO, we can clearly see that they are similar to our previous results and therefore acceptable!

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

- ***Step 12 - Linearity test***

The linearity test figure are reported in the SVN at :
/seismic/BSC-ISI/X2/BSC5/Data/Figures/Linearity_Test/

- LLO_ISI_BSC5_Linearity_test_20130425.fig
- LLO_ISI_BSC5_Linearity_test_20130425.pdf

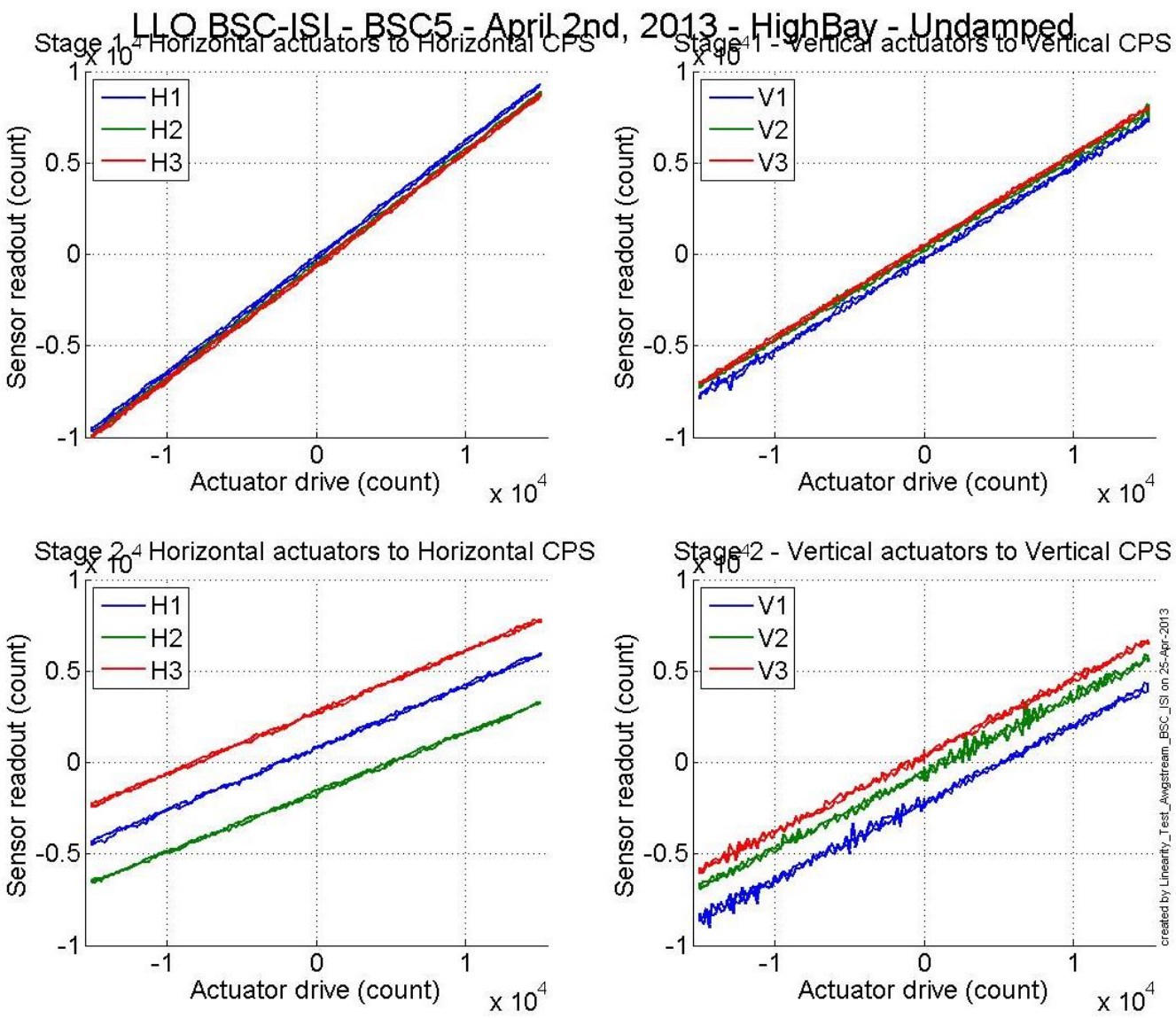


Figure 16 - Linearity Test

Slope – Offset:

		Slope	Offset	Average slope	Variation from average (%)
Stage 1	ST1 - H1	0.62801	-161	0.6240	0.65
	ST1 - H2	0.62254	-543		-0.23
	ST1 - H3	0.62140	-644		-0.41
	ST1 - V1	0.50262	-213	0.5000	0.51
	ST1 - V2	0.49699	308		-0.61
	ST1 - V3	0.50054	479		0.10
Stage 2	ST2 - H1	0.34195	786	0.3347	2.17
	ST2 - H2	0.32559	-1639		-2.72
	ST2 - H3	0.33653	2738		0.55
	ST2 - V1	0.42217	-2183	0.4178	1.06
	ST2 - V2	0.41490	-564		-0.68
	ST2 - V3	0.41622	378		-0.37

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

Previous Results:

Averages (LHO Unit 1 & 2, LLO Unit 1, 2, 3 & 4)							
		Slope	Offset	Average slope	Standard Deviation to Average Slope	% Slope Previous Units/ LLO Unit 5 Slope	% Avg Slope of Previous Units / LLO Unit 5 Avg Slope
Stage 1	ST1 - H1	0.627	-49.580	0.622	0.779	0.202	0.34
	ST1 - H2	0.623	-197.340			-0.090	
	ST1 - H3	0.616	-144.634			0.903	
	ST1 - V1	0.502	229.552	0.504	-0.361	0.204	-0.70
	ST1 - V2	0.501	816.814			-0.884	
	ST1 - V3	0.507	270.927			-1.386	
Stage 2	ST2 - H1	0.344	1212.461	0.341	0.771	-0.456	-1.86
	ST2 - H2	0.341	1218.370			-4.797	
	ST2 - H3	0.338	1928.248			-0.519	
	ST2 - V1	0.415	-253.495	0.414	0.432	1.619	1.00
	ST2 - V2	0.414	266.354			0.145	
	ST2 - V3	0.411	574.729			1.320	

Looking at the average Slopes from the Previous BSC-ISI Units, we can see that this Unit follows the general trend.

Acceptance criteria:

- Horizontal and vertical slopes of the triplet actuators x BSC-ISI x sensors: Average slope +/- 2.5%

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

- ***Step 13 – Transfer functions – Local to Local***

Data files measurement of local to local transfer functions in SVN at:
/svncommon/SeiSVN/seismic/BSC-ISI/X2/BSC5/Data/Transfer_Functions/Measurements/Undamped

- LLO_ISI_BSC5_Data_L2L_10mHz_100mHz_ST1_ST2_20130426-005239.mat
- LLO_ISI_BSC5_Data_L2L_100mHz_700mHz_ST1_ST2_20130425-192948.mat
- LLO_ISI_BSC5_Data_L2L_700mHz_10Hz_ST1_ST2_20130426-045538.mat
- LLO_ISI_BSC5_Data_L2L_10Hz_100Hz_ST1_ST2_20130425-165257.mat
- LLO_ISI_BSC5_Data_L2L_100Hz_500Hz_ST1_ST2_20130425-150806.mat
- LLO_ISI_BSC5_Data_L2L_500Hz_1000Hz_ST1_ST2_20130425-134338.mat

Script file for processing and plotting local to local transfer functions in SVN at:
/svncommon/SeiSVN /seismic/BSC-ISI/X2/Scripts/Control_Scripts

- Step_1_TF_L2L_10mHz_1000Hz_LLO_ISI_BSC2.m

Figures of local to local transfer functions (Main couplings) in SVN at:
/svncommon/SeiSVN/seismic/BSC-ISI/X2/BSC5/Data/Figures/Transfer_Functions/Measurements/Undamped

- LLO_ISI_BSC5_TF_L2L_Raw_from_ST1_ACT_to_ST1_CPS_2013_04_25.fig
- LLO_ISI_BSC5_TF_L2L_Raw_from_ST1_ACT_to_ST1_L4C_2013_04_25.fig
- LLO_ISI_BSC5_TF_L2L_Raw_from_ST2_ACT_to_ST2_CPS_2013_04_25.fig
- LLO_ISI_BSC5_TF_L2L_Raw_from_ST2_ACT_to_ST2_GS13_2013_04_25.fig

Measured of local to local transfer functions in the SVN at:
/svncommon/SeiSVN /seismic/BSC-ISI/X2/BSC5/Data/Transfer_Functions/Simulations/Undamped

- LLO_ISI_BSC5_TF_L2L_Raw_10mHz_1000Hz_2013_04_25.mat

Note 1: The transfer functions are measured from the Output filter bank (excitation variable) to the input (IN1) of the input filter bank. The transfer functions presented below are raw transfer functions without any electronic compensation of the sensor electronic. The actuator and the coil driver electronic compensation are introduced in these transfer functions.

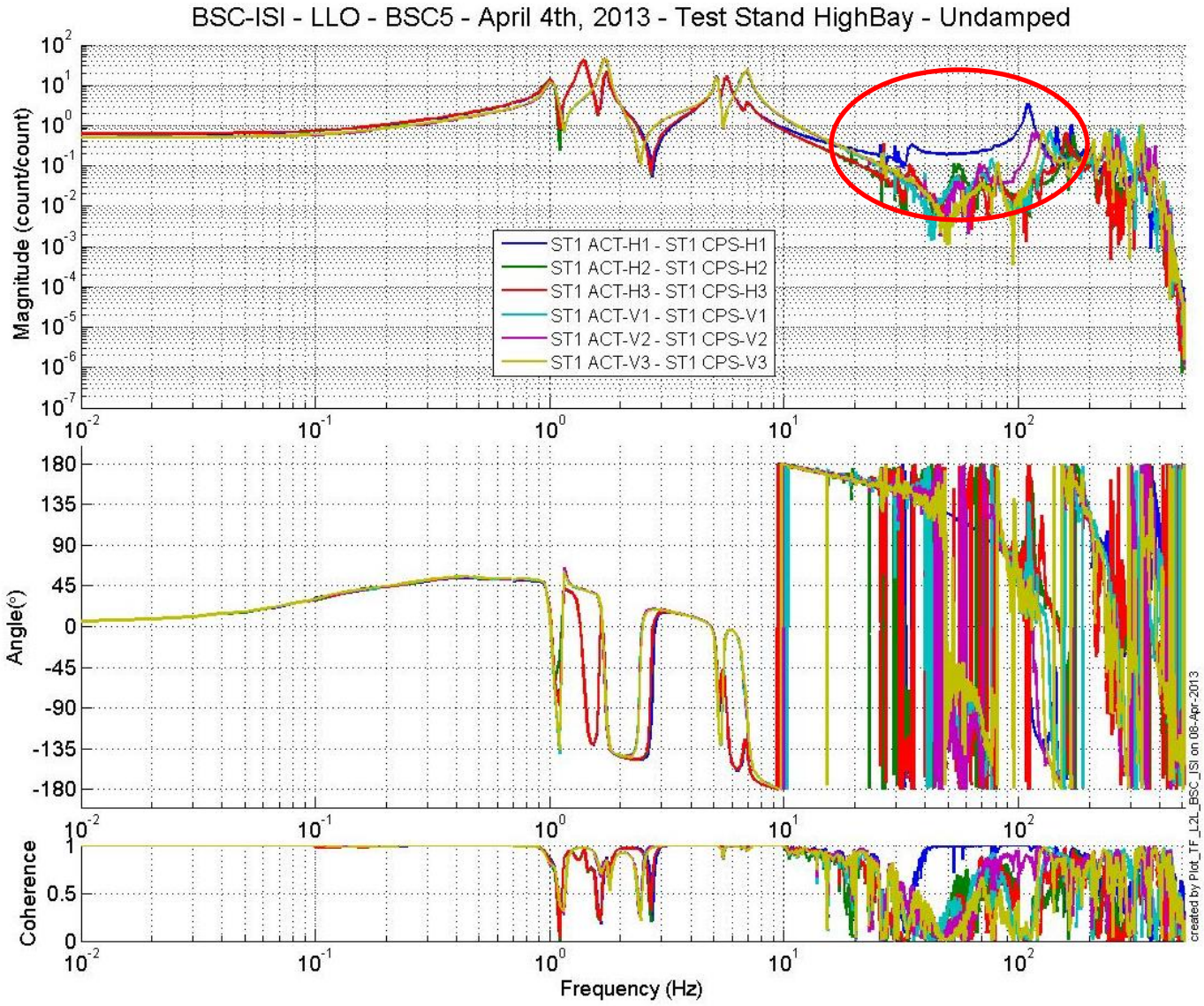
Note 2: The L4Cs are out of phase (should be -90 before 1Hz). A minus sign is added in the calibration filters that convert count to nm/s.

Note 3: We don't see any resonance of the Test Stand at 16Hz on Stage 1 CPS like LHO did.

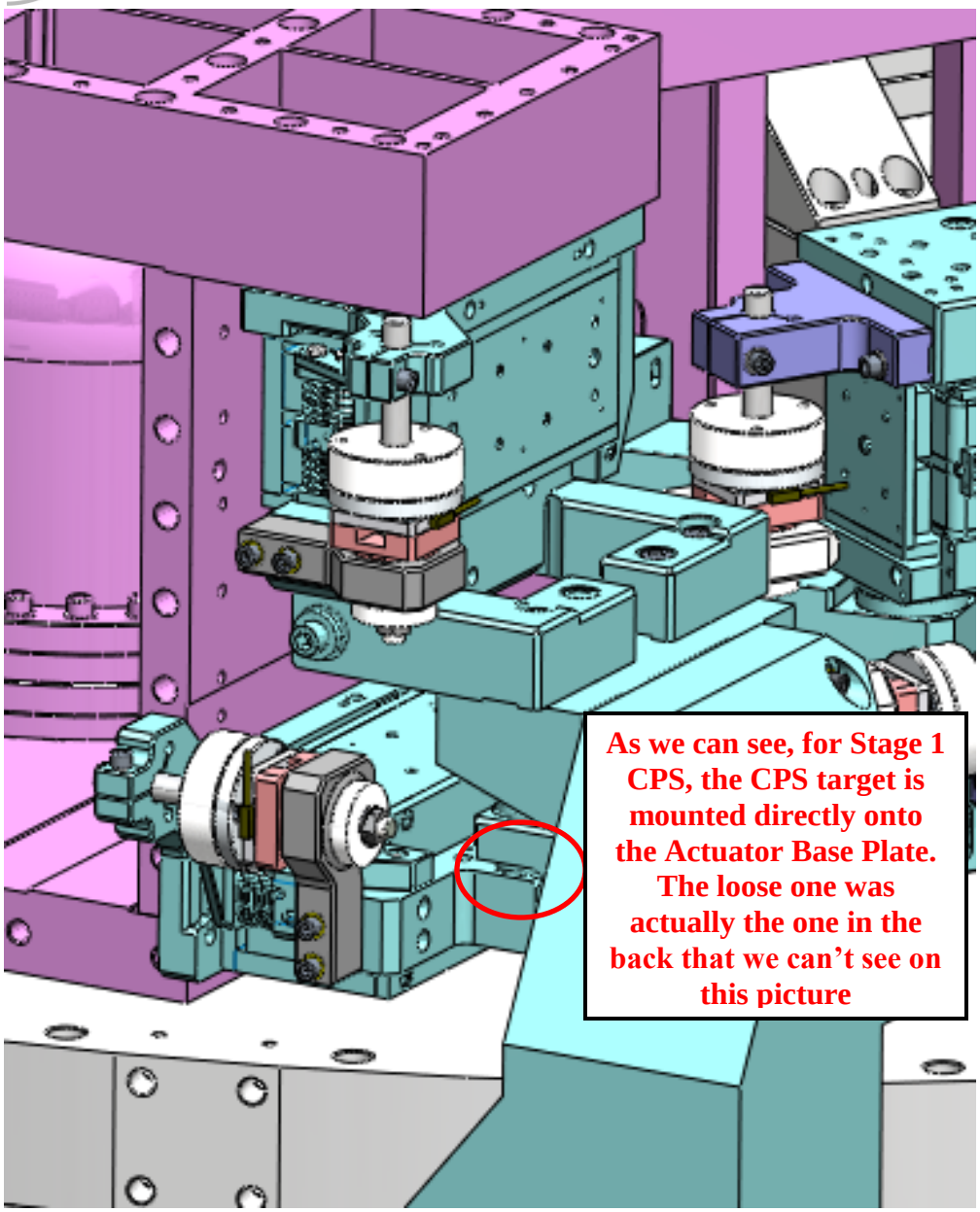
Note 4: The first high frequency resonance observed on stage 1 by the L4C is at 220Hz. The next resonance is observed at 299Hz. The first mode of the blade has been measured at ~250Hz at LASTI, but it shouldn't be the Blades' resonances thanks to the Tuned Mass Dampers (tuned at 253 ± 4 Hz Hz) already installed on Stage 0-1 Blades on this Unit.

Note 5: There is a poor coherence on the GS13 transfer functions. It can be explained by the weak drive of the fine actuators. Moreover, the stage 2 of the ISI is strongly excited by the fans of the clean rooms. These two factors strongly affect the quality of the measurements. Also, we might have an issue with the GS-13 gain because they were saturating a lot, which can also explain the poor quality of the signal.

Note 6: On the ST2-ACT to ST2-GS13 transfer functions, the first high frequency resonances are observed at 98 and 114Hz (electric noise, harmonic of 60Hz?) and 140Hz.



This is the first set of TF we took of BSC 5 and as we can clearly see on the Figure above, we had a different comportment of the Structure seen by Stage 1 H1 CPS. We couldn't see this difference in comportment on any other instrument. So we concluded that it was something very local to Stage 1 H1 CPS. After further investigations, we found that one of the spherical washers of Stage 1 H1 Actuator was misaligned forbidding the flat washer to sit flat against its mounting bracket.


As we can see, for Stage 1 CPS, the CPS target is mounted directly onto the Actuator Base Plate. The loose one was actually the one in the back that we can't see on this picture

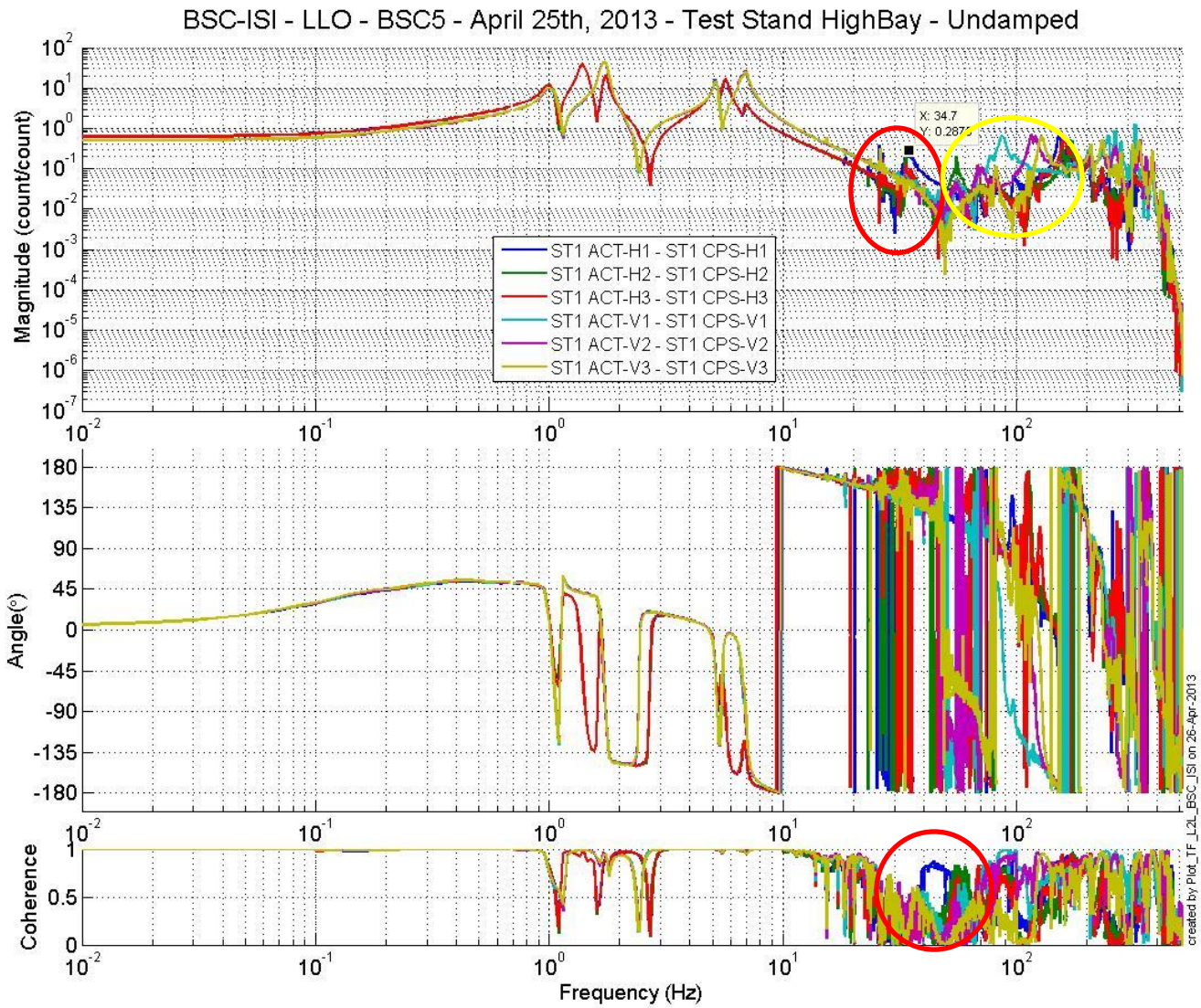


Figure 17: TF L2L Raw - ST1 Act to ST1 CPS

Note: We can still notice a difference of behavior between Stage H1 and the other Horizontal CPS (circled in red) at 34.7Hz. We suspected that H1 Actuator was not torqued properly to Stage 1, even if on the L4C TF we couldn't see anything suspect. So we took everything down in order to check the torque value on this actuator and didn't find anything suspect. We put everything back together and had no changes in the TF. After further investigations, it looks like it is coming from the test stand it was tested on (same behavior can be seen on BSC3, last BSC tested on this stand and later on, in the LVEA and inside the chamber, this resonance disappears).

We can also noticed a difference in behavior between Stage 1 V1 and the rest of the Vertical CPS.

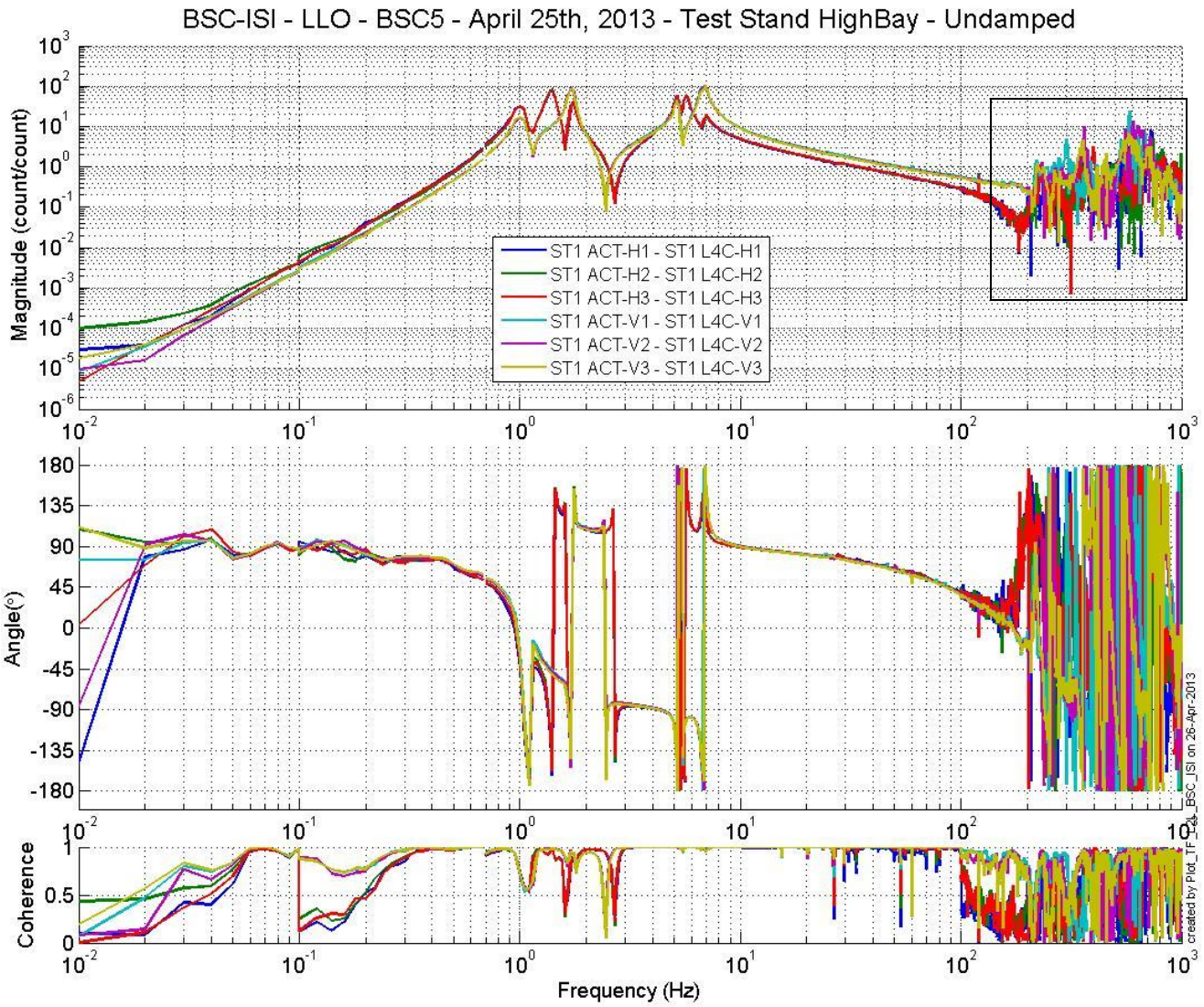
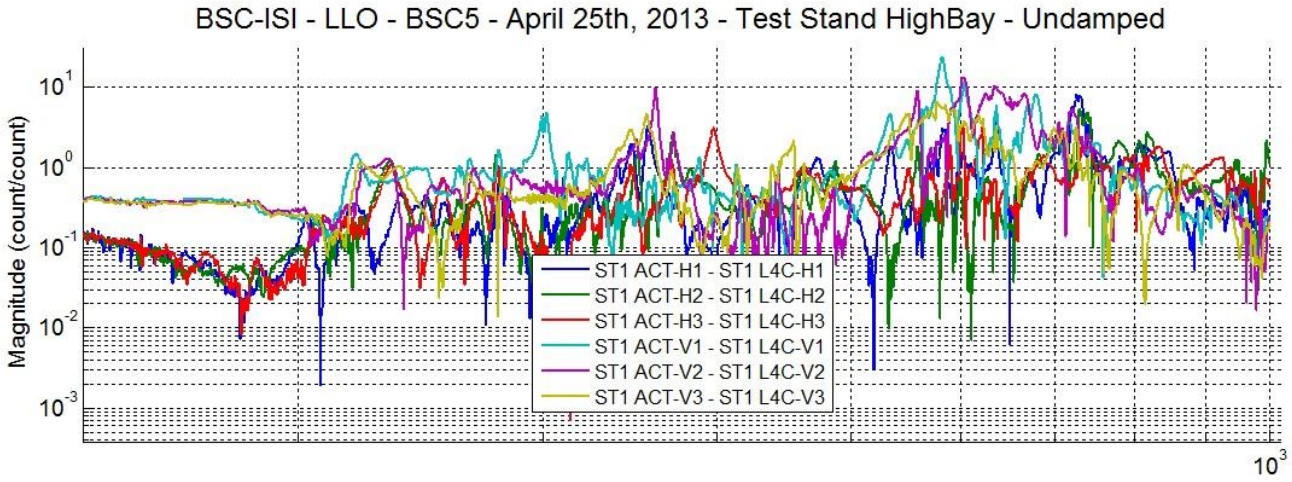


Figure 18: TF L2L Raw - ST1 Act to ST1 L4C



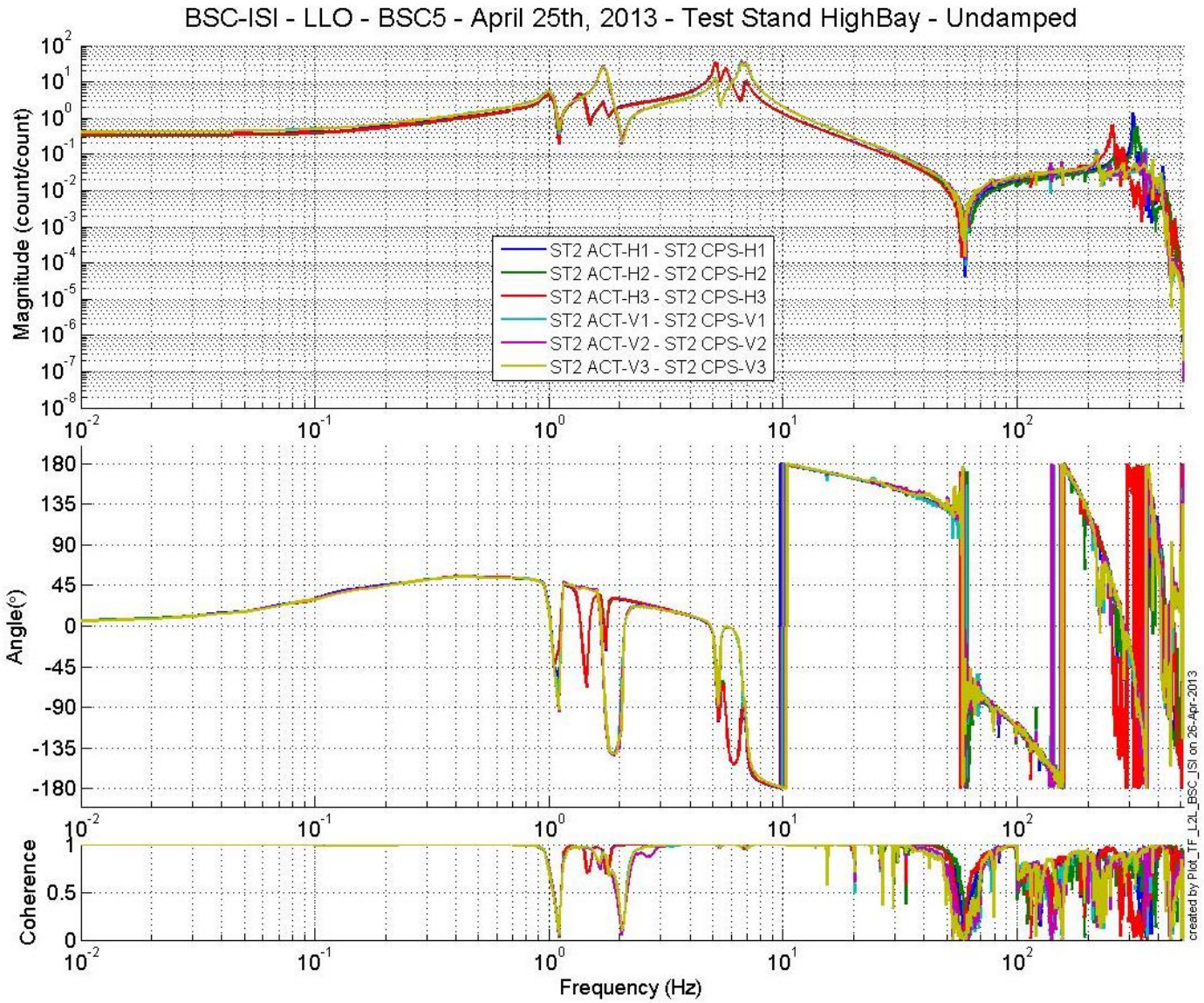


Figure 19: TF L2L Raw - ST2 Act to ST2 CPS

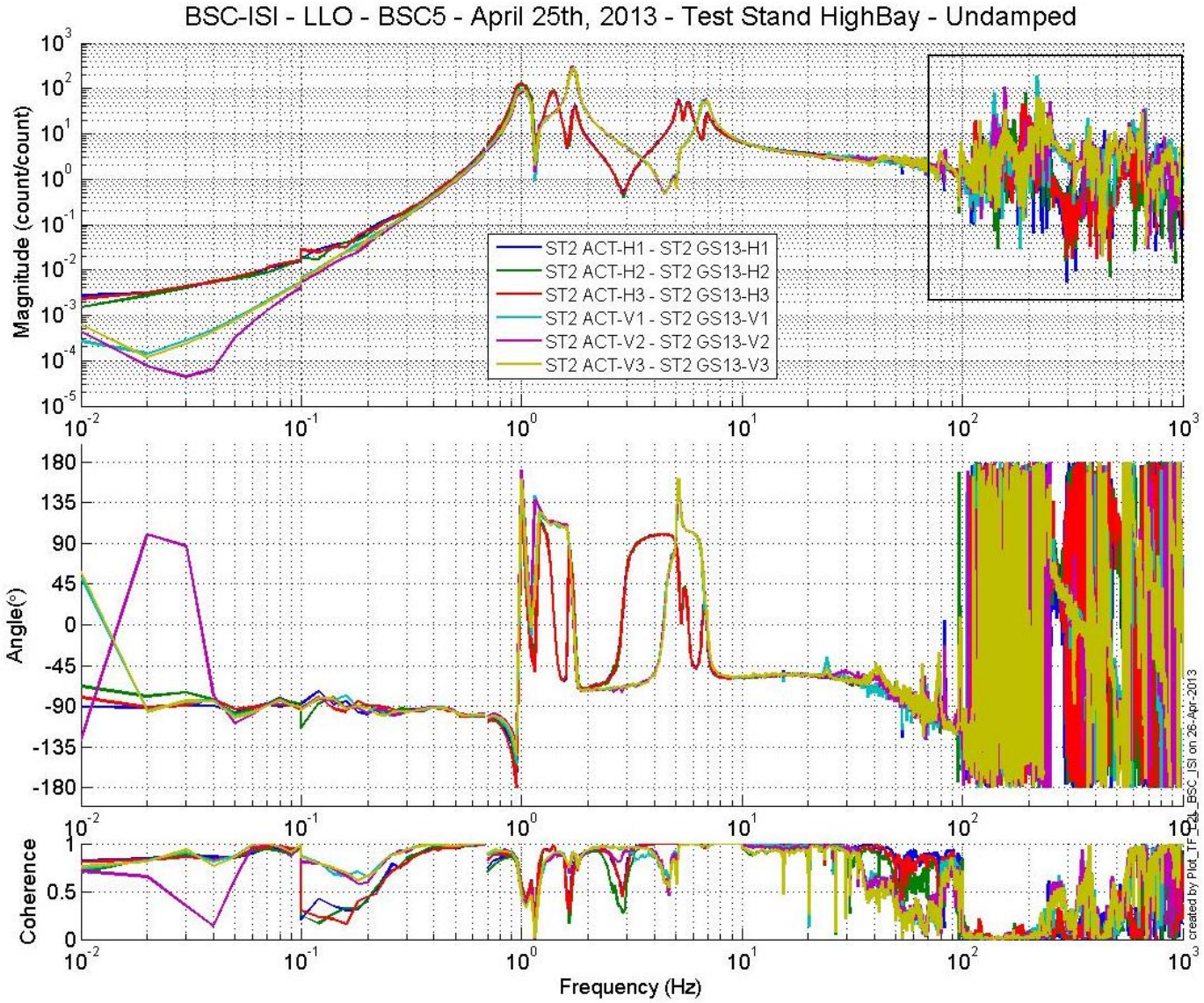
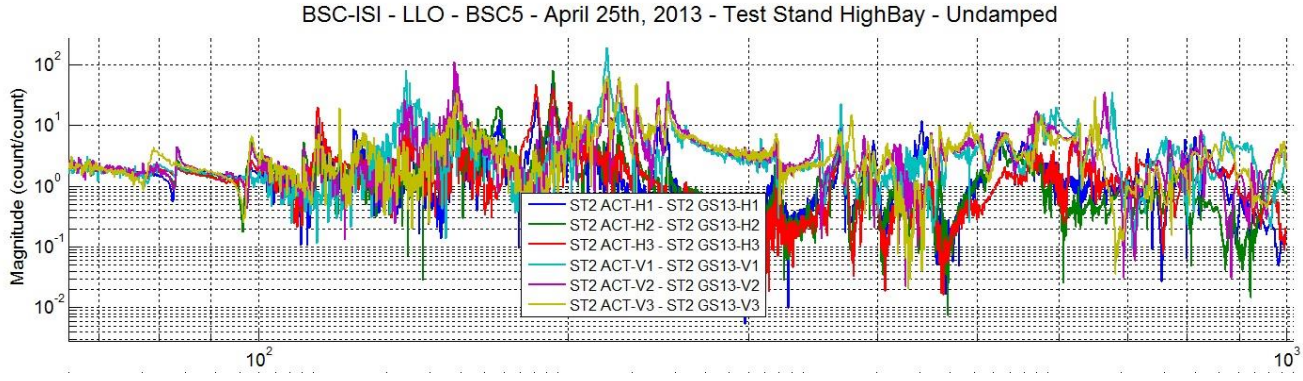


Figure 20: TF L2L Raw - ST2 Act to ST2 GS13



We then also decided to compare these results with previous Units (LHO BSC8 & LLO BSC2).

Figures of local to local transfer functions (Main couplings) in SVN at:
/svncommon/SeiSVN/seismic/BSC-ISI/X2/BSC5/Data/Figures/Transfer_Functions/Simulations/Undamped

- LLO_ISI_BSC5_Comparison_TF_L2L_ST1_ACT_H_to_ST1_CPS_H_20110722_vs_20130425.fig
- LLO_ISI_BSC5_Comparison_TF_L2L_ST1_ACT_H_to_ST1_L4C_H_20110722_vs_20130425.fig
- LLO_ISI_BSC5_Comparison_TF_L2L_ST1_ACT_V_to_ST1_CPS_V_20110722_vs_20130425.fig
- LLO_ISI_BSC5_Comparison_TF_L2L_ST1_ACT_V_to_ST1_L4C_V_20110722_vs_20130425.fig
- LLO_ISI_BSC5_Comparison_TF_L2L_ST2_ACT_H_to_ST2_CPS_H_20110722_vs_20130425.fig
- LLO_ISI_BSC5_Comparison_TF_L2L_ST2_ACT_H_to_ST2_GS13_H_20110722_vs_20130425.fig
- LLO_ISI_BSC5_Comparison_TF_L2L_ST2_ACT_V_to_ST2_CPS_V_20110722_vs_20130425.fig
- LLO_ISI_BSC5_Comparison_TF_L2L_ST2_ACT_V_to_ST2_GS13_V_20110722_vs_20130425.fig

Measured of local to local transfer functions in the SVN at:
/svncommon/SeiSVN /seismic/BSC-ISI/X2/BSC5/Data/Transfer_Functions/Simulations/Undamped

- LLO_ISI_BSC5_TF_L2L_Raw_10mHz_1000Hz_2013_04_25.mat

/svncommon/SeiSVN /seismic/BSC-ISI/X1/BSC8/Data/Transfer_Functions/Simulations/Undamped

- LLO_ISI_BSC8_TF_L2L_Raw_10mHz_1000Hz_2011_07_22.mat

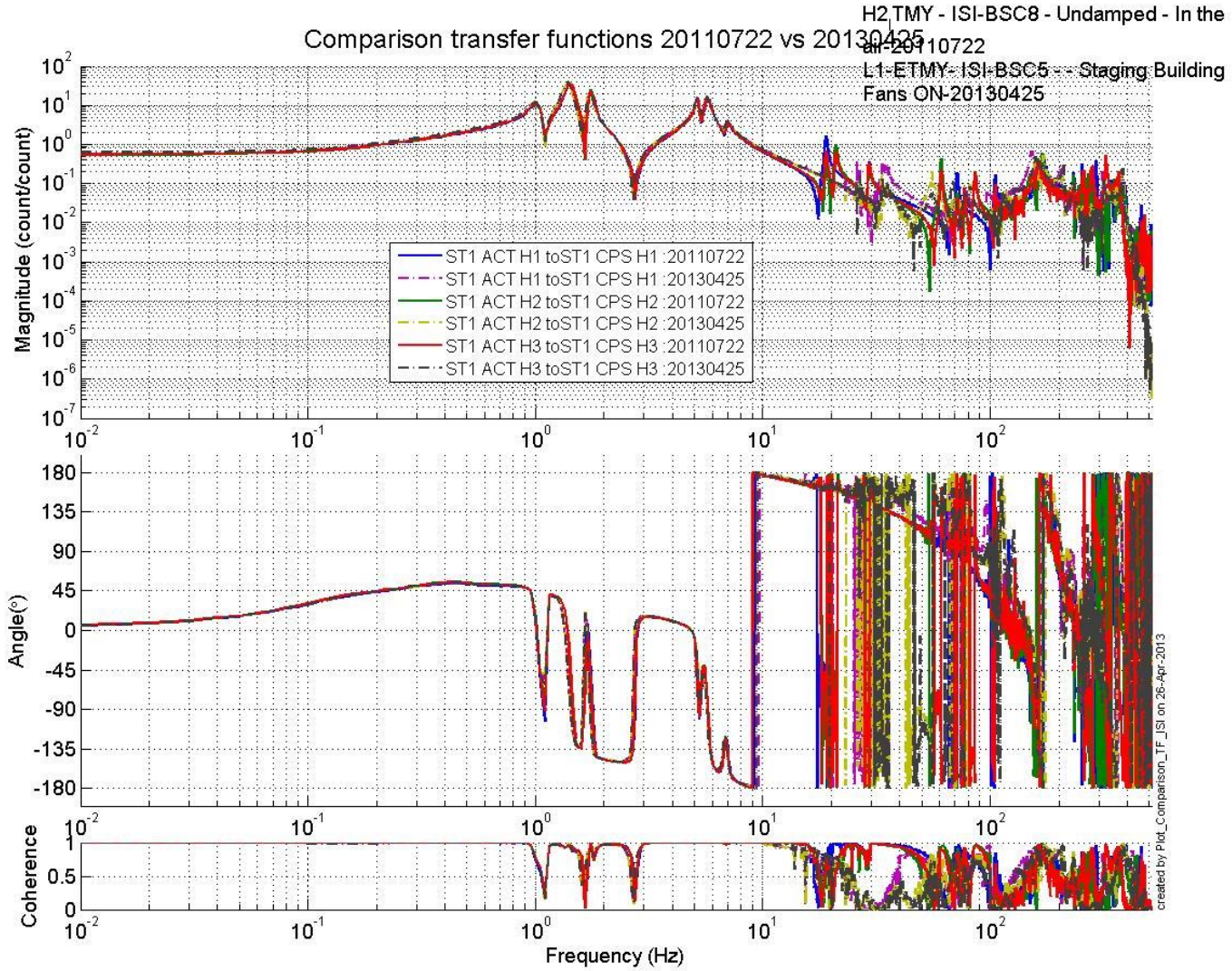


Figure 21: TF L2L Comparison between LLO BSC 5 & LHO BSC 8– H ST1 Actuator to ST1 CPS

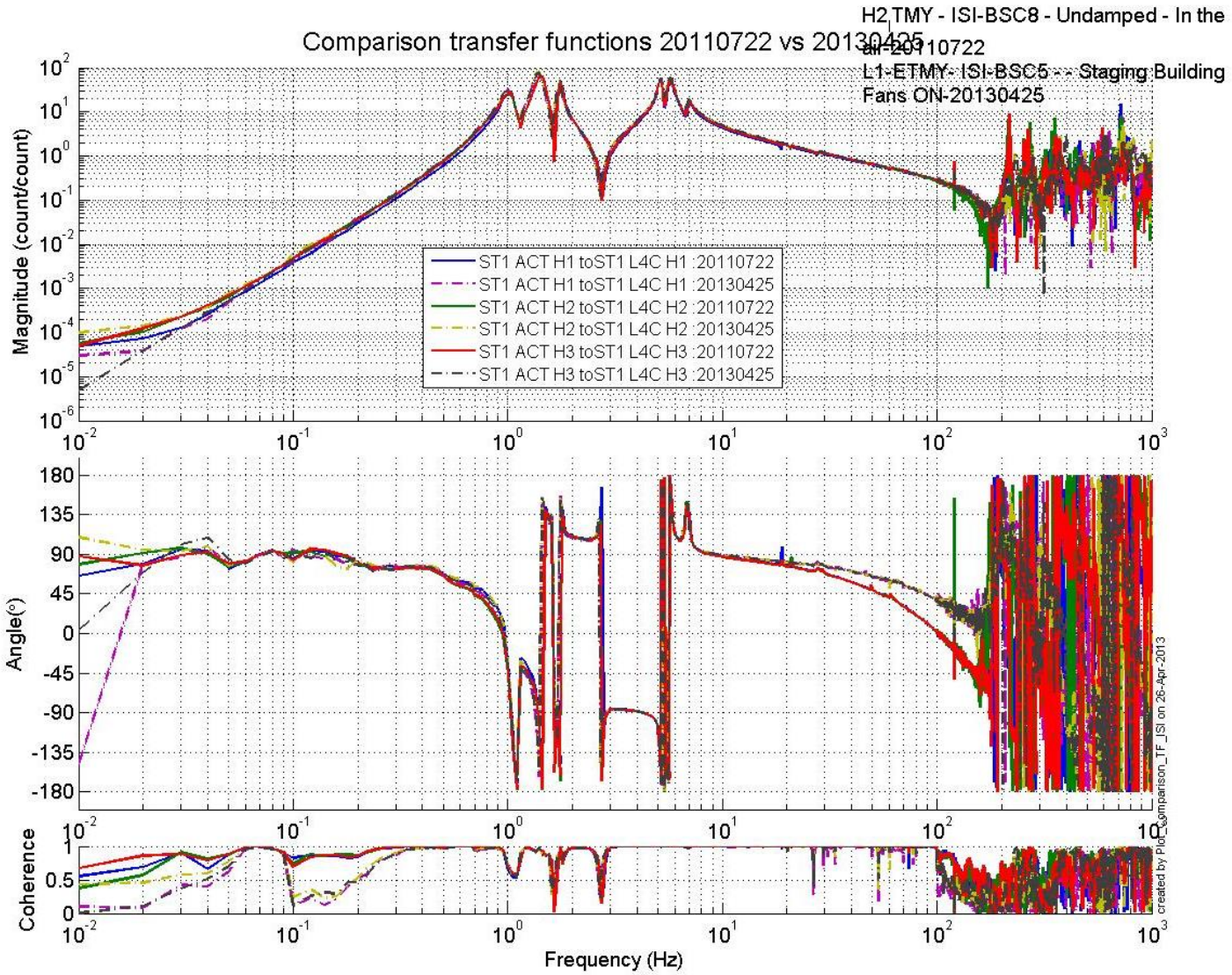


Figure 22: TF L2L Comparison between LLO BSC 5 & LHO BSC 8 – H ST1 Actuator to ST1 L4C

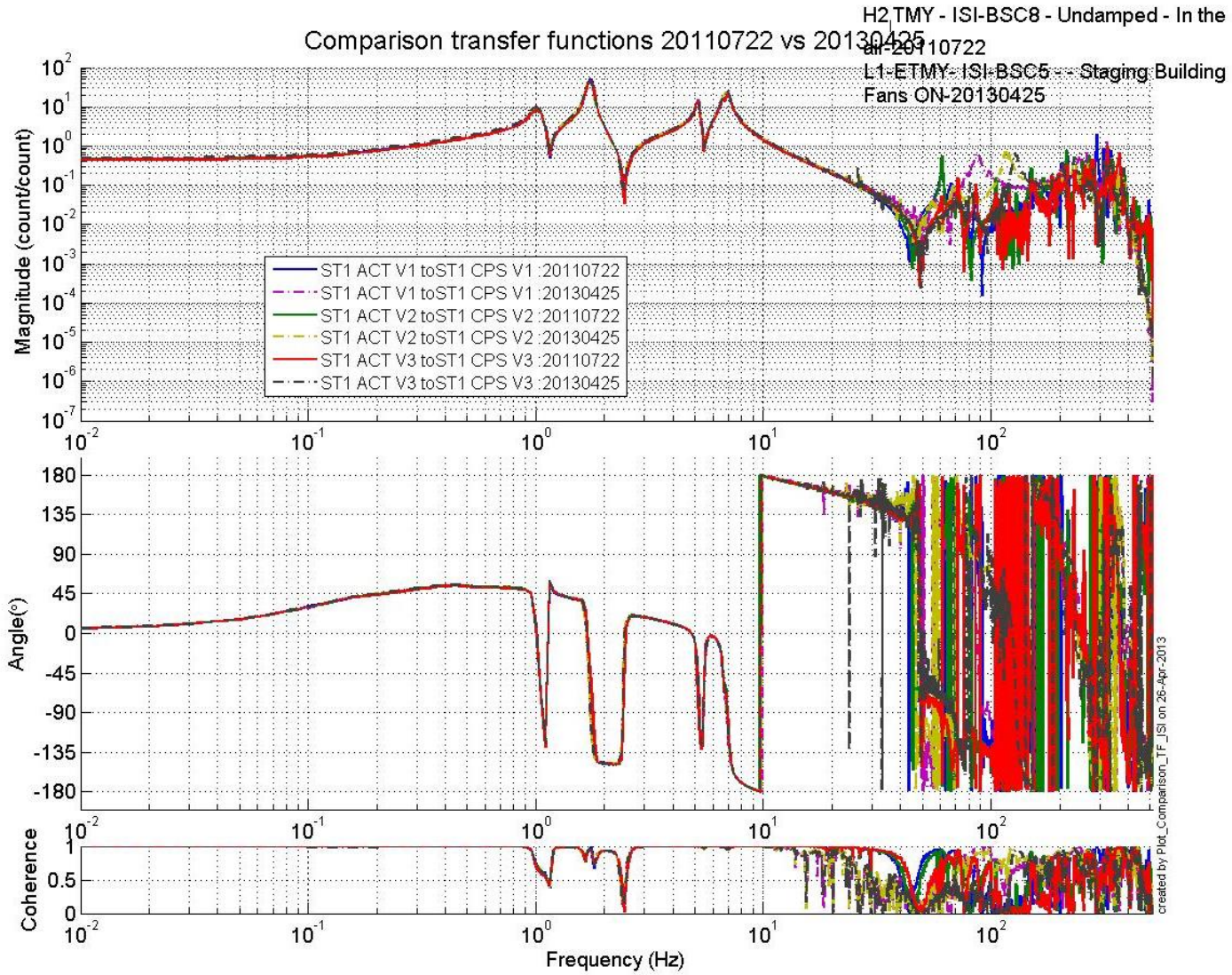


Figure 23: TF L2L Comparison between LLO BSC 5 & LHO BSC 8 – V ST1 Actuator to ST1 CPS

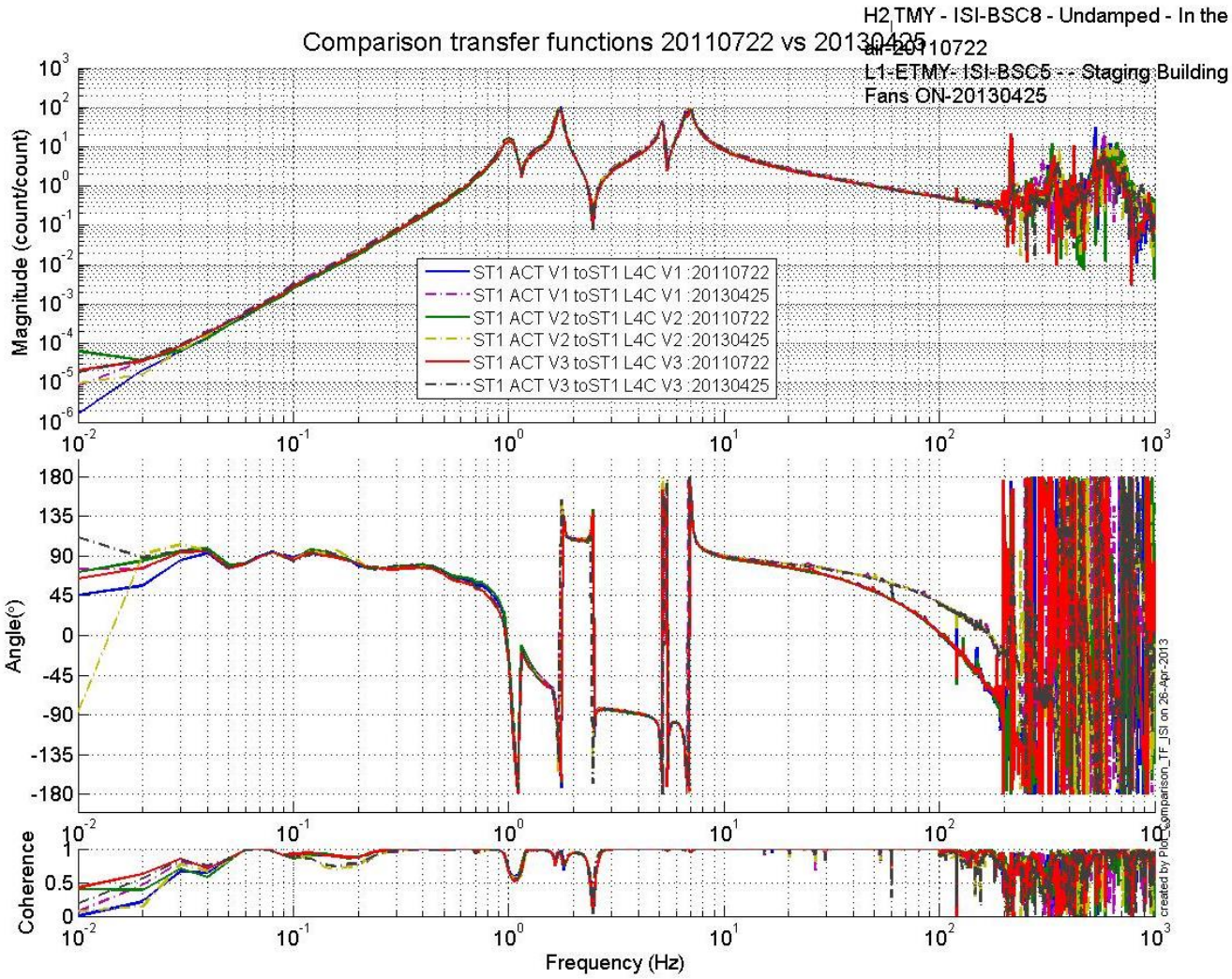


Figure 24: TF L2L Comparison between LLO BSC 5 & LHO BSC 8 – V ST1 Actuator to ST1 L4C

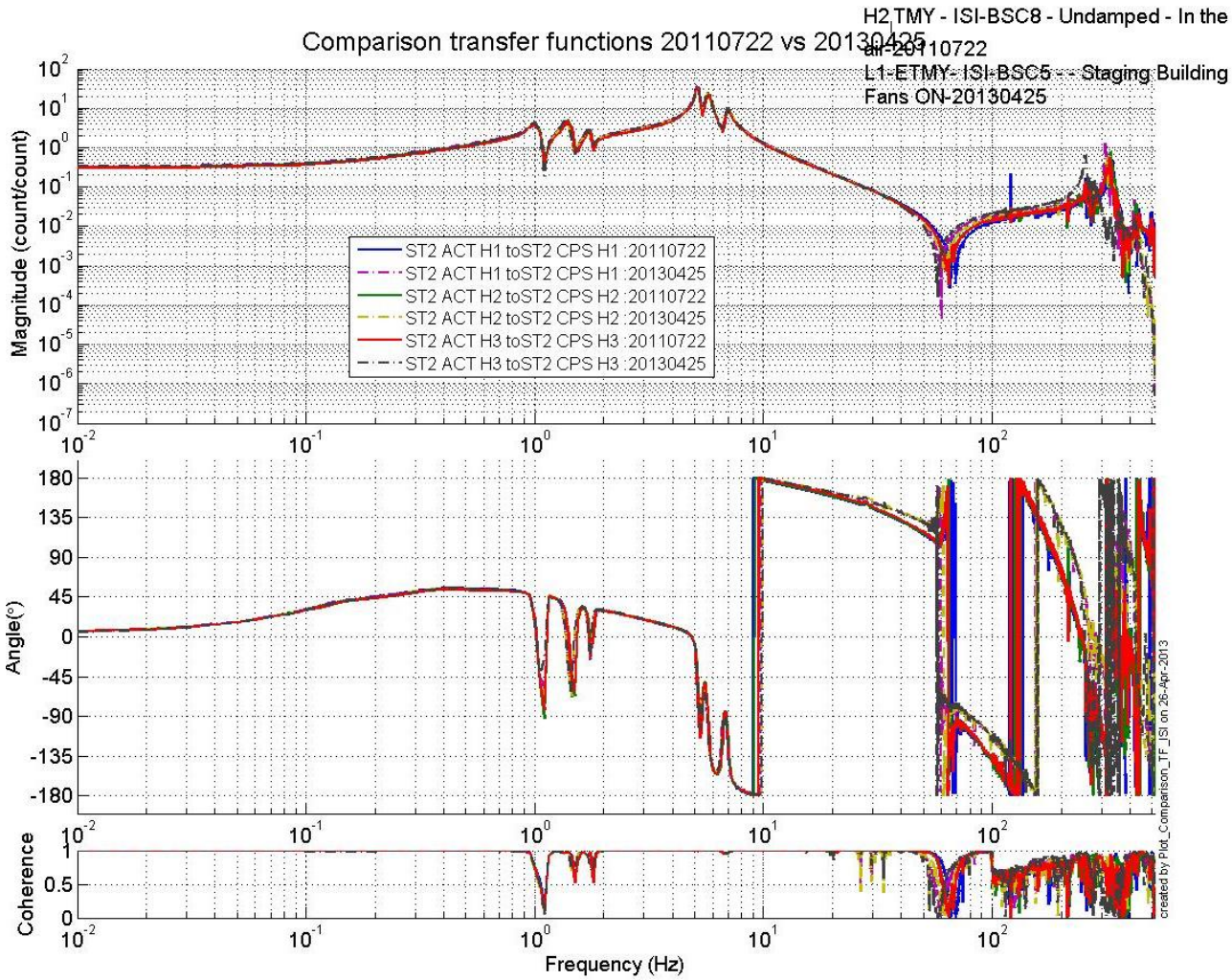


Figure 25: TF L2L Comparison between LLO BSC 5 & LHO BSC 8 – H ST2 Actuator to ST2 CPS

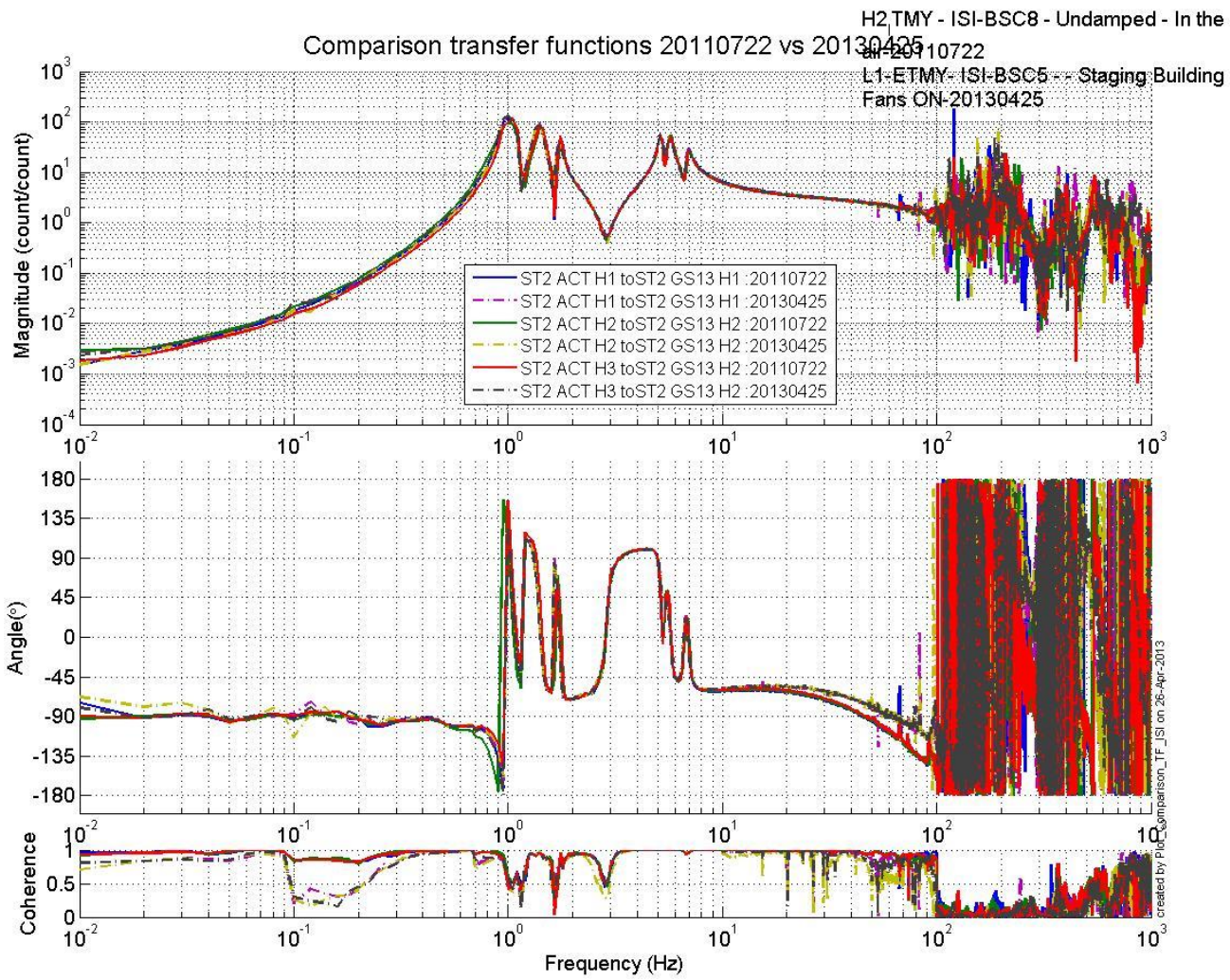


Figure 26: TF L2L Comparison between LLO BSC 5 & LHO BSC 8 – H ST2 Actuator to ST2 GS13

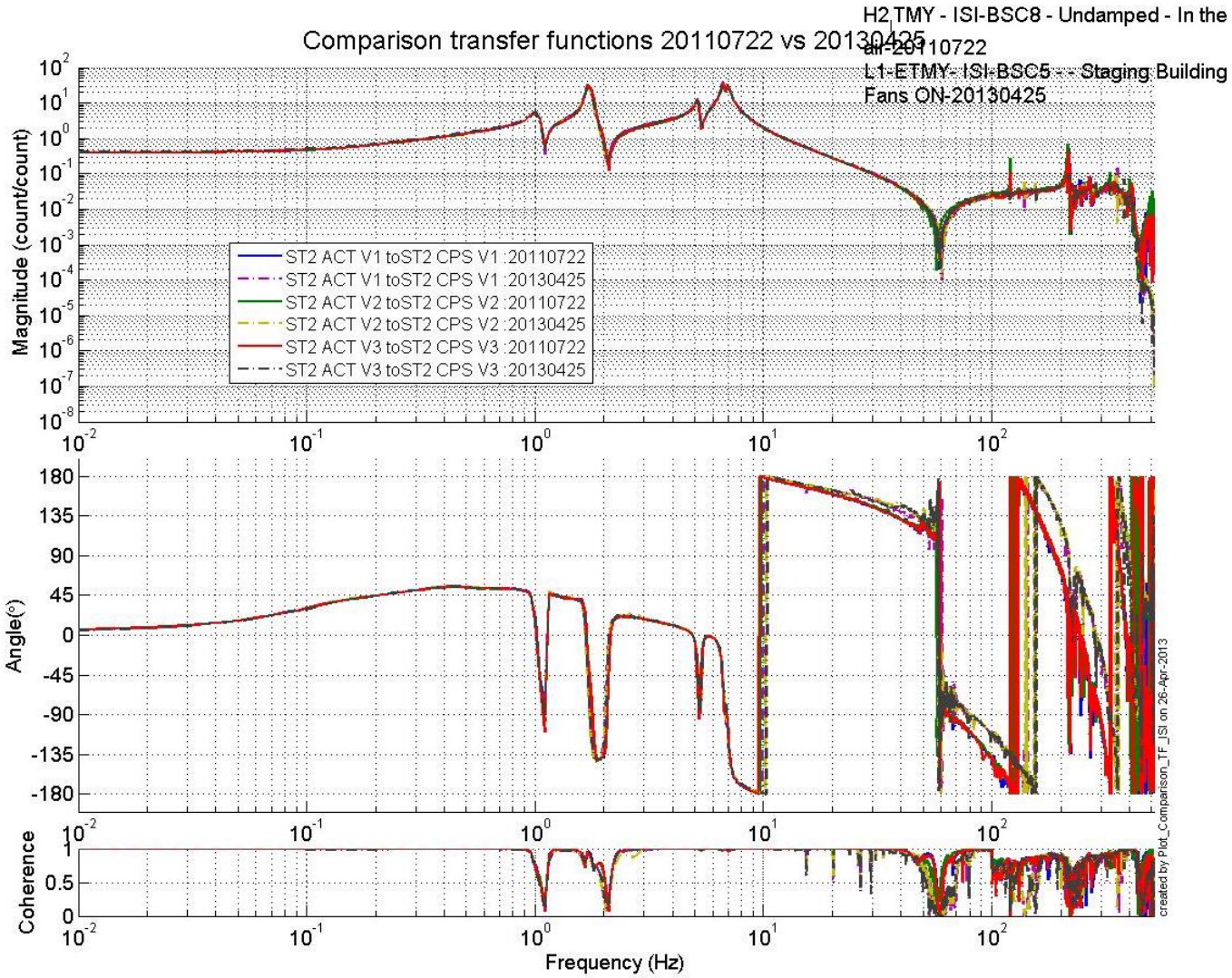


Figure 27: TF L2L Comparison between LLO BSC 5 & LHO BSC 8 – V ST2 Actuator to ST2 CPS

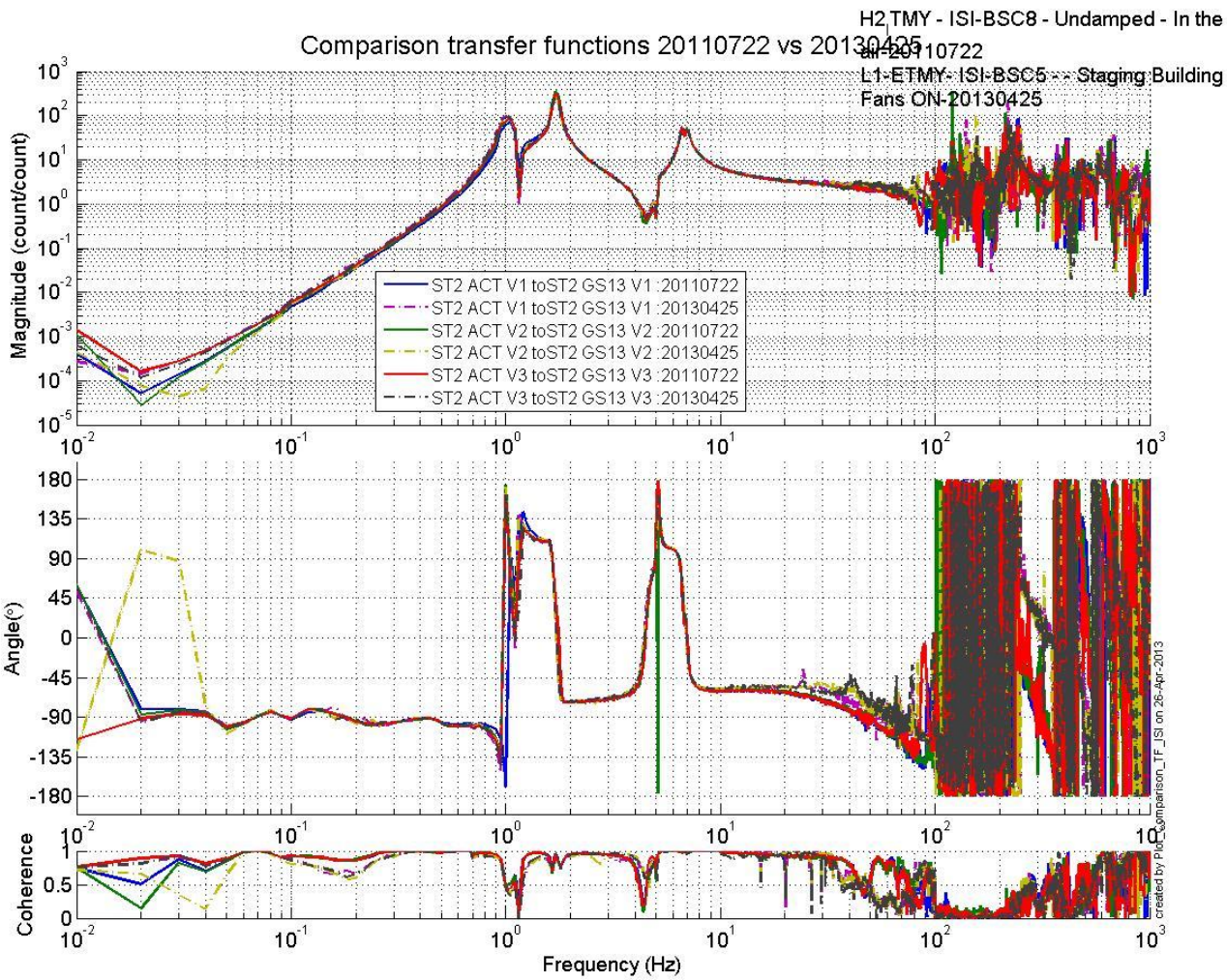


Figure 28: TF L2L Comparison between LLO BSC 5 & LHO BSC 8 – V ST2 Actuator to ST2 GS13

By comparing LLO BSC 5 to LHO BSC 8, we can conclude that BSC 5 is in the general trend of the previous BSCs built!

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

Due to schedule pressure, it was decided it was reasonable to postpone the following tests. They will be performed during Phase II.

- ***Step 14 - Symmetrization – Calibration***

Not performed

- ***Step 15 – Change of base – Cartesian to Local - Simulations***

Not performed

- ***Step 16- Transfer functions - Cartesian to Cartesian - Measurements***

Not performed

- ***Step 17 - Lower Zero Moment Plan***
  - ***Step 17.1 - Stage 1 - LZMP***

Not performed

  - ***Step 17.2 - Stage 2 - LZMP***

Not performed

- ***Step 18- Damping Loops – Transfer function – Simulations***
  - ***Step 18.1 - Damping Loops – Stage 2***

Not performed

  - ***Step 18.2 - Damping Loops – Stage 1***

Not performed

- ***Step 19- Damping Loops – Powerspectra***

Data files measurement of damping Power Spectra in SVN at:
/svncommon/SeiSVN/seismic/BSC-ISI/X2/BSC5/Data/Spectra/Damping

Figures of local to local transfer functions (Main couplings) in SVN at:
/seisvn/seismic/BSC-ISI/X2/BSC5/Data/Figures/Spectra/Damping

Figure 29: LLO ISI BSC4 ASD CT CART Stage 1 L4C Undamped vs Damping

Figure 30: LLO ISI BSC4 ASD m CART Stage 1 L4C Undamped vs Damping

Figure 31: LLO ISI BSC4 ASD CT CART Stage 2 GS 13 Undamped vs Damping

Figure 32: LLO ISI BSC4 ASD m CART Stage 2 GS 13 Undamped vs Damping

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

- ***Step 20- Isolation Loops – for one unit per site***

Not performed

IV. BSC-ISI testing Summary

This is the fifth and last "aLigo BSC-ISI" tested at LLO. The testing procedure document E1000483-v3 was used. Tests were done during April 2013.

The ISI-BSC5 is waiting for officially validation. All results are posted on the SVN at:
https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/X2/BSC5/Data

FAILED AND WAIVED TESTS

1- List of tests that failed/waived and won't be redone

- **Step III. 4.1 Push in the General Coordinates Z/RZ:** This test doesn't meet the requirements but it is really hard to have good results for the RZ directions because all the three pushers need to make sure they're only moving horizontally which is not always the case. Plus, the Step 4.2 "Push locally" passes, so from that we can conclude that the system moves freely and has no restraints. So we decide to waive that test result, plus it has failed for other Units in the past that turned out to be fine.
- **Step III. 6 Coil Driver, Cabling and Resistance Check:** This test fails by 0.1 Ohms on 3 actuators. We have already seen that in the past on other Units. The requirements might be a little bit too strict. These results seem coherent with the other Units, so we don't think we need to redo this test.

2- List of tests that failed/waived, that need to be re-done during phase 2

- **Step III. 10 & 11 Static Testing** – These tests fail but not by much and looking at the average values obtained from the previous Units, we can conclude that the criteria is maybe a little bit too strong.
- **Step III.12 Linearity Test:** This test fails by a small amount, but is in the general trend of all the previous Units. We will redo it in the Y-end.

3- List of tests skipped that won't be performed because not feasible during phase II (i.e. stage 0 leveling)

- **Step II.5 –** Check level of Stage 0 after top-bottom plate assembly
- **Step II.8** – Blade 0-1 Post Launch Angle – No need for this test, the budget mass looks good and we already reposition the Blades after noticing a gap between the Blade and its Spacer on Stage 0-1 (see comment on Step 9 – Vertical Spring Constant).

4- List of tests skipped that we won't do because they are not essential (i.e. redundant with another test)

- **Step III.3 – Measure the Sensor gap -** This test was not performed. The sensor gaps have not been measured. These sensors have already been checked at LASTI. Moreover, risks of scratching the target are so high that we preferred not performing this test. In the future, this test will be removed from the testing procedure.
- **Step III.8 – Vertical sensor calibration -** The test is not realized in a proper way to evaluate accurately the calibration of the vertical CPS.

5- Lists of tests skipped that needs to be done during phase II.

- **Step III.14 – Symmetrization – Calibration**
- **Step III.15 – Change of bases – Cartesian to local - Simulations**
- **Step III.16 – Transfer functions – Cartesian to Cartesian - Simulations**
- **Step III.17 – Lower Zero Moment Plan**
- **Step III.18.1 – Damping Loops – Stage 2**
- **Step III.18.2 – Damping Loops – Stage 1**
- **Step III.20 – Isolation loops**

The ISI-BSC will be moved from the HighBay to the Y-End test stand as soon as it has been approved.