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**aLIGO BSC-ISI, Pre-integration Testing report,
Phase II (before and after cartridge install)**

E1100849 – V2

Sebastien Biscans, Jim Warner, Hugo Paris

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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

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

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

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Introduction

The BSC-ISI testing is performed in three phases:

- 1) BSC-ISI, Pre-integration Testing, Phase I (post-assembly, in the staging building)
- 2) BSC-ISI, Pre-integration Testing, Phase II: Final tests done before insertion in the chamber
- 3) BSC-ISI, Integration Phase Testing: Procedure and results related to the commissioning in the chamber.

The ISI-BSC9 was moved from the Staging building to the VEA test stand July 2013.

This document presents results of tests (Phase II) performed on the ISI-BSC9 (ETMX) before installation in the chamber.

All results are posted on the SVN at:

<https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/H1/ETMX/>

The following type of document can be found in the SVN:

- Excell spreadsheet (.xls)
- Data location
- Figures location
- Masses distribution scheme (ppt)

1. Phase II-a

1. Hardware changes

1. CPS – E1100369

CPS have not been replaced since phase I testing in the staging building.

2. GS13 – E1100740

GS13 have not been replaced since phase I testing in the staging building.

3. L4C – E1100740

L4C have not been replaced since phase I testing in the staging building.

4. T240 – E1100740

T240 have not been replaced since phase I testing in the staging building.

5. Cables – E1100822

The cables installed on ISI-BSC3 are reported in the table below. Further information can be found in E1100822.

6. Misc

No hardware changes since phase I testing in the staging building.

2. Electronic Inventory

This table reports the electronic equipment used in the LVEA.

3. Models Modifications

The model was updated and recompiled since MEDM screens were modified

4. Mass distribution

Here is the payload distribution of the ISI. SUS-QUAD and TMS are installed.

Stage 1	
Location	Weight (lb)
Corner 1	59.5
Corner 2	54
Corner 3	19.5
Total	133

Table 1 - Payload Stage 1

Stage 1 payload is unchanged since first installation in the staging building.

Stage 2 - 2612lb - 5% = 2481lb

Mass Budget - Mass type	Quantity	Weight	Unit	Weight (lb)
D1003136	12	50	lb	600
D1003161	7	47.4	lb	332
type 0	1	.6	lb	4.8
type 1	5	1.1	lb	13.2
type 2	0	2.2	lb	2.2
type 3	4	4.5	lb	9
type 4	8	7.9	lb	39.5
type 5	2	15.6	lb	78
type 6	6	27.2	lb	163.2
				1193.9

Table 2 - Payload Stage 2

This is the Stage 2 Seismic payload. Add ~900 lbs for a quad and ~450 for the TMS and the total payload is 2591lb.

There is a 12lb difference with the payload installed in the staging building.

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

5. Basic functionalities just after installing the BSC-ISI on the teststand

☐☐ Pressure sensors

All pressure sensors are working.

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/H1/ITMX/Data/Static_Tests/

- H1_ISI_ETMX_Pressure_Sensors_Check_Calibrated_2020_09_19_3 0:6:[.mat](#)

Sensors	Pressure (kPa)		
	Corner 1	Corner 2	Corner 3
ST1-L4C-P	-.01913	.2	-.9
ST1-L4C-D	99.5777	99.3	100.9
ST1-GS13-P	.4876	.1044	.98549
ST1-GS13-D	100.041	100	102
ST1-T240-P	100.4	101.2	100.75

Table 3 - Geophones Pressure sensors

Test result: Passed: X Failed: ____ Waived: ____

i. Spectra

Spectra of the instrument can be found in the SVN at:

<seismic/BSC-ISI/H1/ETMX/Data/Spectra/Undamped/>

- [H1_ISI_ETMX_ASD_m_LOC_CPS_T240_L4C_GS13_2020_09_20_3 6:7:.mat](#)

<https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/H1/ETMX/Data/Figures/Spectra/Undamped/>

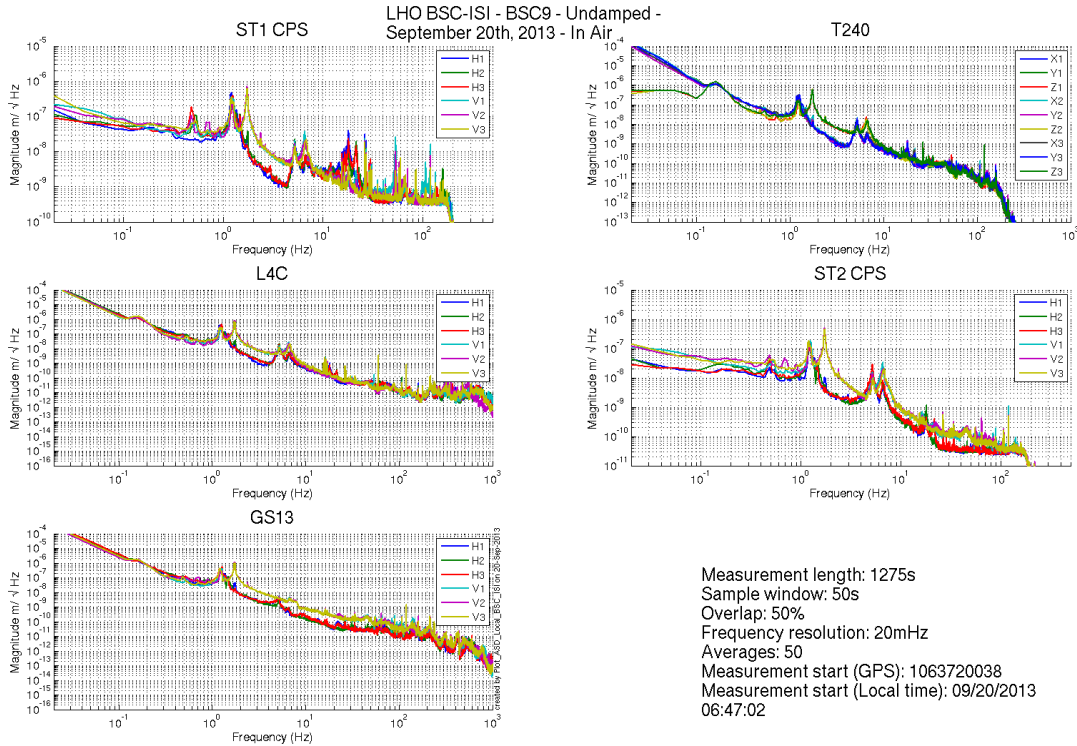
[H1_ISI_ETMX_ASD_m_LOC_CPS_T240_L4C_GS13_2020_09_20_36:7:.fig](#)

Figure 1 - Spectra inboard instruments - ISI Unlocked

Test result: Passed: X Failed: ____ Waived: ____

ii. Actuators-cables resistance

Test result: Passed: ____ Failed: ____ Waived: X



iii. Offsets CPS Unlocked vs locked

Table 4 - Locked vs Unlocked Position

Test result: Passed: Failed: Waived:

iv. Offset local drive

Results of this test can be found in the SVN at:

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/H1/ETMX/Data/Static_Tests/

- [H1 ISI TST Offset Local Drive 20130923.mat](#)

		Sensors					
		ST1 - H1	ST1 - H2	ST1 - H3	ST1 - V1	ST1 - V2	ST1 - V3
Actua tors	ST1 - H1	3956	1591	1592	30	7.2	-2.7
	ST1 - H2	1579	3947	1582	-.7	34.7	-12.4
	ST1 - H3	1587	1599.4	3946	-2.8	2.1	19
	ST1 - V1	.3	-150.3	68.4	3031.2	-501.5	-478.4
	ST1 - V2	73.8	16.8	-147	-481.2	3067.2	-501.7
	ST1 - V3	-144.7	78.5	39.5	-515	-488.2	3047

Table 5 - Static Tests – Local to Local - Stage 1

		Sensors					
		ST2 - H1	ST2 - H2	ST2 - H3	ST2 - V1	ST2 - V2	ST2 - V3
Actuators	ST2 - H1	2251	350	335	6	-4	9
	ST2 - H2	327	2231	343	13	-5	-14
	ST2 - H3	327	336	2240	2	16	12
	ST2 - V1	73	107	-174	2698	358	33
	ST2 - V2	-177	73	115	44	2660	339
	ST2 - V3	112	-184	72	364	30	2686

Table 6 - Static Tests – Local to Local - Stage 2

Test result:

Passed: X

Failed:

Waived:

v. Offset Cartesian drive

Tests in the Cartesian basis were not performed. Disregard.

vi. Range of motion

The range of motion of the table is measured by pushing on the table in a direction collinear to the CPS. The Static tests results can be found on the SVN at:

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/H1/ETMX/Data/Static_Tests/

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1	-14540	802	17629	32169	38
ST1 - H2	-15877	53	16166	32043	38
ST1 - H3	-15811	-467	16336	32147	38
ST1 - V1	-13259	-260	12755	26014	31
ST1 - V2	-12273	839	13933	26206	31
ST1 - V3	-13369	-103	13143	26512	32
ST2 - H1	-8903	737	10348	19251	6
ST2 - H2	-8240	1218	10686	18926	6
ST2 - H3	-9601	-75	9426	19027	6
ST2 - V1	-10684	824	12289	22973	7
ST2 - V2	-10732	627	11969	22701	7
ST2 - V3	-9055	2381	13799	22854	7

Table 7 - Range of motion - Actuator drive in the LVEA

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

vii. Linearity test

The test was performed on Sept 23, 2013.

The data of the linearity test can be found on the SVN at:
 seismic/BSC-ISI/H1/ETMX/Data/Linearity_Test/

- [H1 ISI TST Linearity test 20130923.mat](#)

The figures of the linearity test can be found on the SVN at:
 seismic\BSC-ISI\H1\ETMX\Data\Figures\Linearity_Test\

- [H1 ISI TST Linearity test 20130923.fig](#)

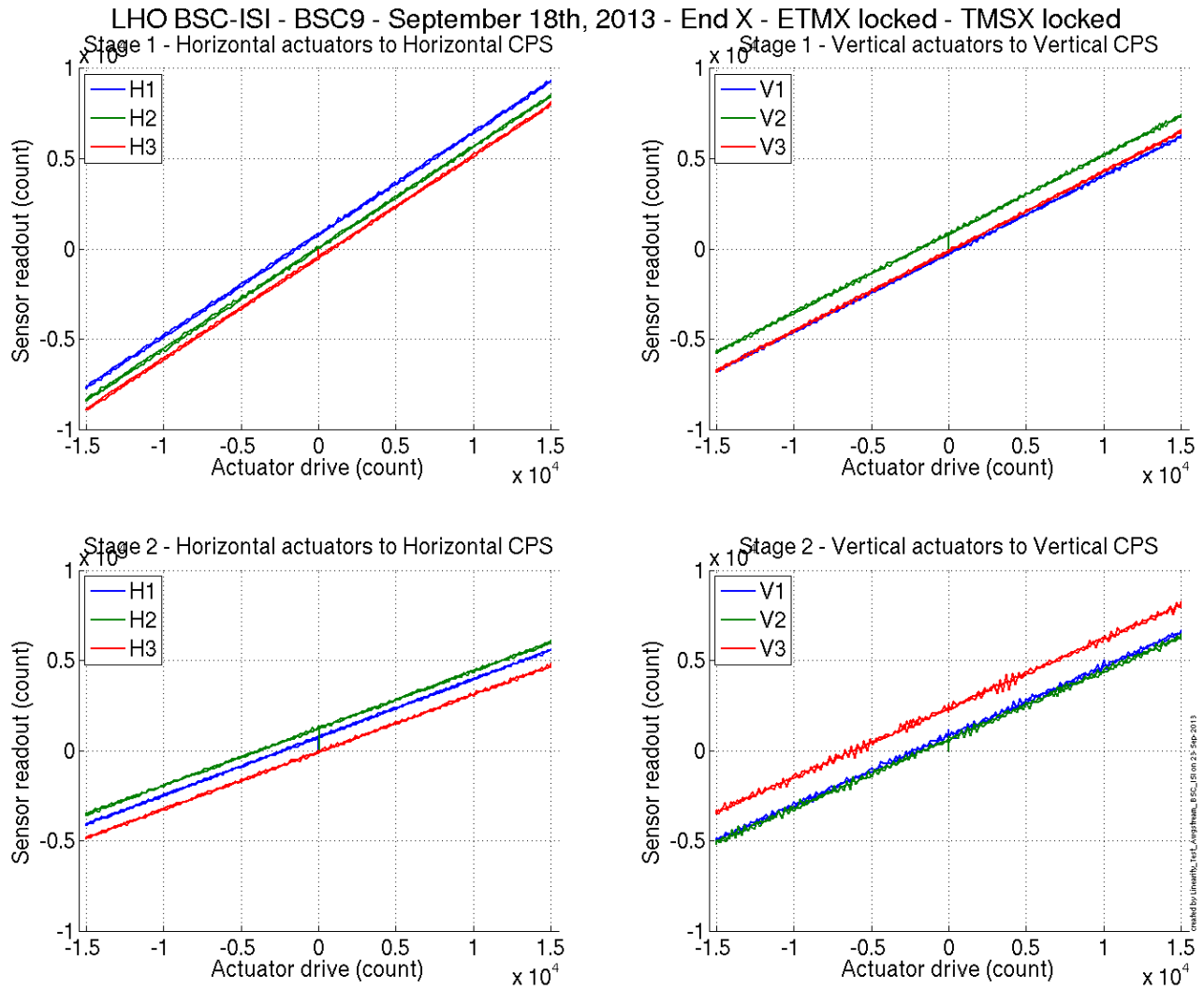


Figure 2 - Linearity test - TMSY - ETMY - At the end station

		Slope	Offset	Average slope	Variation from average(%)
Stage 1	ST1 - H1	.565	817	.563	.3
	ST1 - H2	.561	64		-.3
	ST1 - H3	.563	-454		-.01
	ST1 - V1	.433	264	.437	-.96
	ST1 - V2	.436	834		-.11
	ST1 - V3	.441	-121		1.08
Stage 2	ST2 - H1	.322	738	.319	.89
	ST2 - H2	.317	-1230		-.56
	ST2 - H3	.318	-73		-.33
	ST2 - V1	.383	803	.382	.42
	ST2 - V2	.379	607		-.64
	ST2 - V3	.382	2348		.22

Table 8 - Slope – Offset Linearity test

Note:

Test result: Passed: X Failed: Waived:

6. Transfer functions and Comparison with measurements done in the staging building.

1. At the end station

The parameters for the measurements at the end station are slightly different from those in the staging building. It may be explained by the relative proximity of the cleanroom fans as well as the weaker power delivered by the actuators due to the longer in-air cables.

Measurements data can be found in the SVN at:

SeiSVN/seismic/BSC-ISI/H1/ETMX/Data/Transfer_Functions/Measurements/Undamped:

- H1_ISI_TST_Data_L2L_100mHz_700mHz_ST1_ST2_20130922-040310.mat
- H1_ISI_TST_Data_L2L_700mHz_10Hz_ST1_ST2_20130922-232931.mat
- H1_ISI_TST_Data_L2L_10Hz_100Hz_ST1_ST2_20130921-161730.mat
- H1_ISI_TST_Data_L2L_100Hz_500Hz_ST1_ST2_20130922-180440.mat\
- H1_ISI_TST_Data_L2L_500Hz_1000Hz_ST1_ST2_20130922-134412.mat

Once the data are processed, they can be found in the SVN at:

[/seismic/BSC-ISI/H1/ETMX/Data/Transfer_Functions/Simulations/Undamped/
- H1_ISI_TST_TF_L2L_Raw_2013_09_23.mat](#)

The transfer functions can be found in the SVN at:

seismic/BSC-ISI/H1/ETMX/Data/Figures/Transfer_Functions/Measurements/Undamped/

- [H1_ISI_TST_TF_L2L_Raw_from_ST1_ACT_to_ST1_CPS_2013_09_23.fig](#)
- [H1_ISI_TST_TF_L2L_Raw_from_ST1_ACT_to_ST1_L4C_2013_09_23.fig](#)
- [H1_ISI_TST_TF_L2L_Raw_from_ST1_ACT_to_ST1_T240_2013_09_23.fig](#)

- [H1 ISI TST TF L2L Raw from ST1 ACT to ST2 CPS 2013 09 23.fig](#)
- [H1 ISI TST TF L2L Raw from ST1 ACT to ST2 GS13 2013 09 23.fig](#)
- [H1 ISI TST TF L2L Raw from ST2 ACT to ST1 L4C 2013 09 23.fig](#)
- [H1 ISI TST TF L2L Raw from ST2 ACT to ST1 T240 2013 09 23.fig](#)
- [H1 ISI TST TF L2L Raw from ST2 ACT to ST2 CPS 2013 09 23.fig](#)
- [H1 ISI TST TF L2L Raw from ST2 ACT to ST2 GS13 2013 09 23.fig](#)

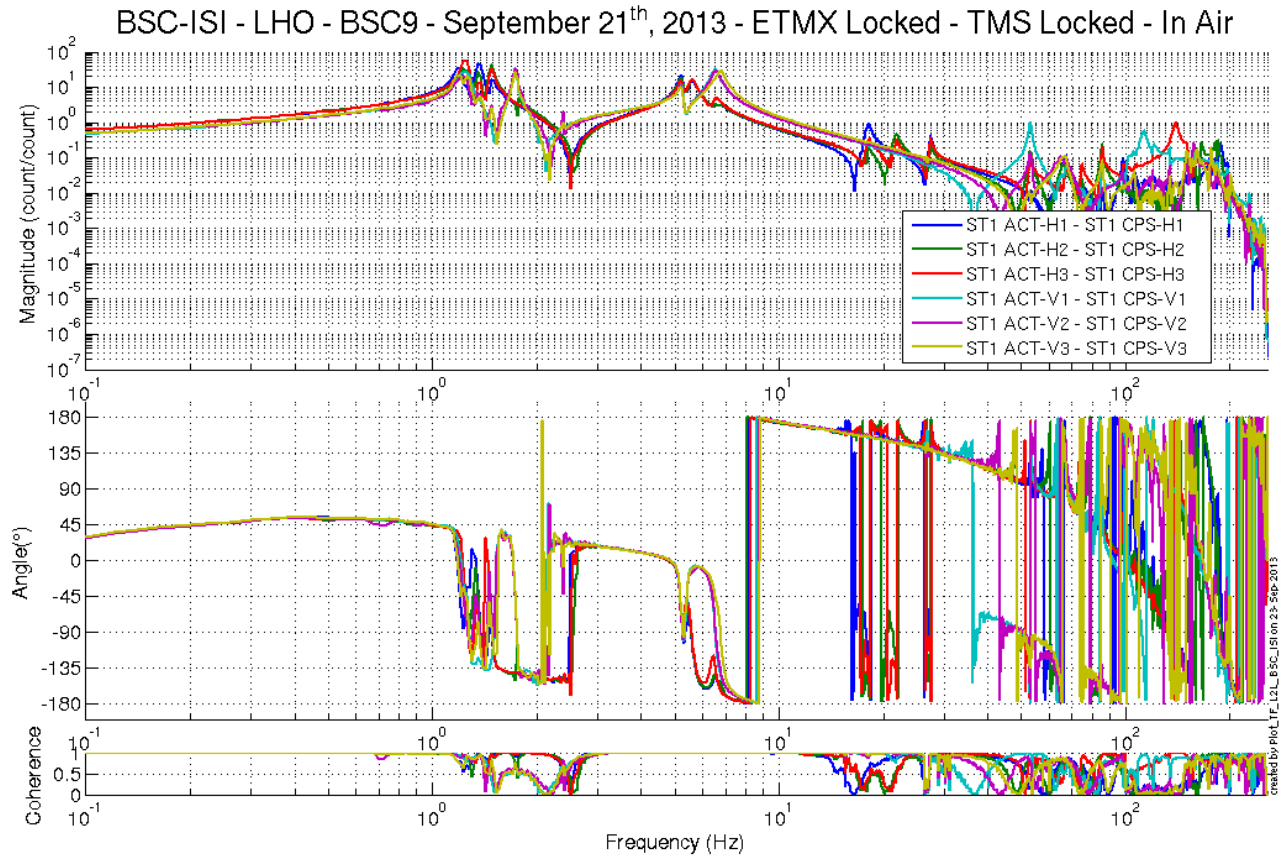


Figure 3 - TF ST1 ACT to ST1 CPS

BSC-ISI - LHO - BSC9 - September 21th, 2013 - ETMX Locked - TMS Locked - In Air

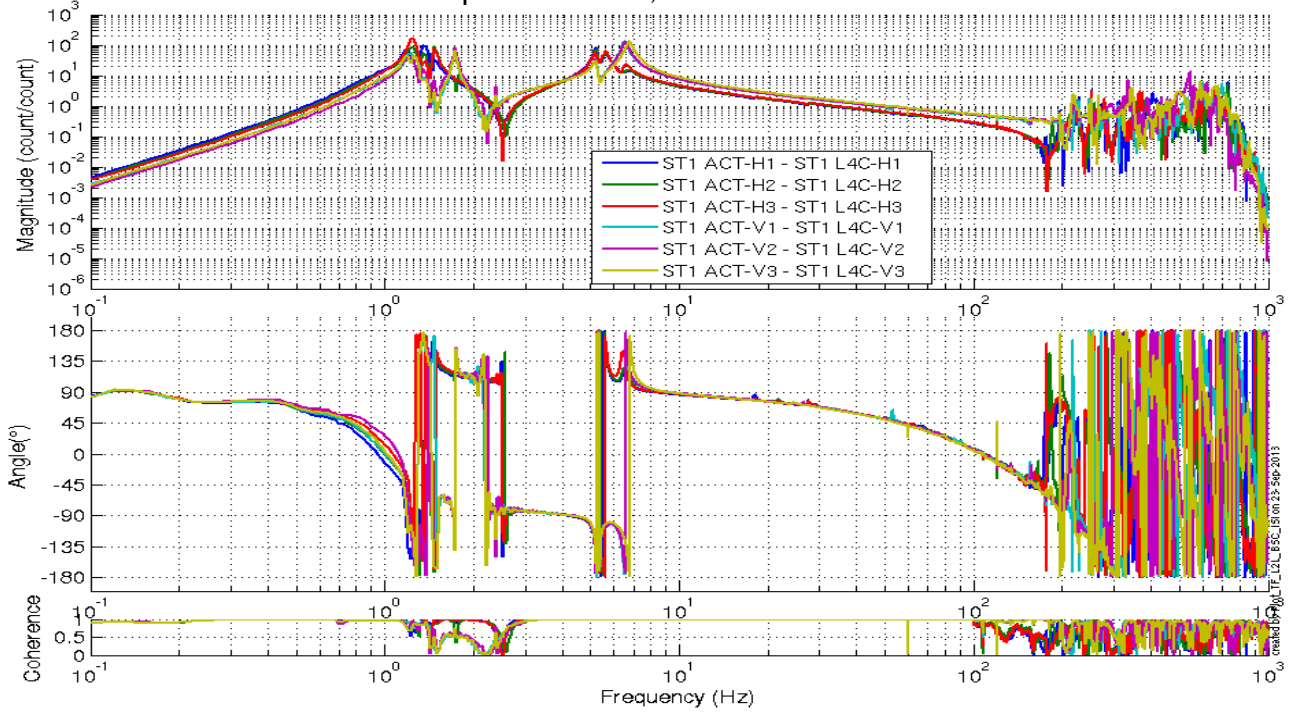


Figure 4 - TF ST1 ACT to ST1 L4C

BSC-ISI - LHO - BSC9 - September 21th, 2013 - ETMX Locked - TMS Locked - In Air

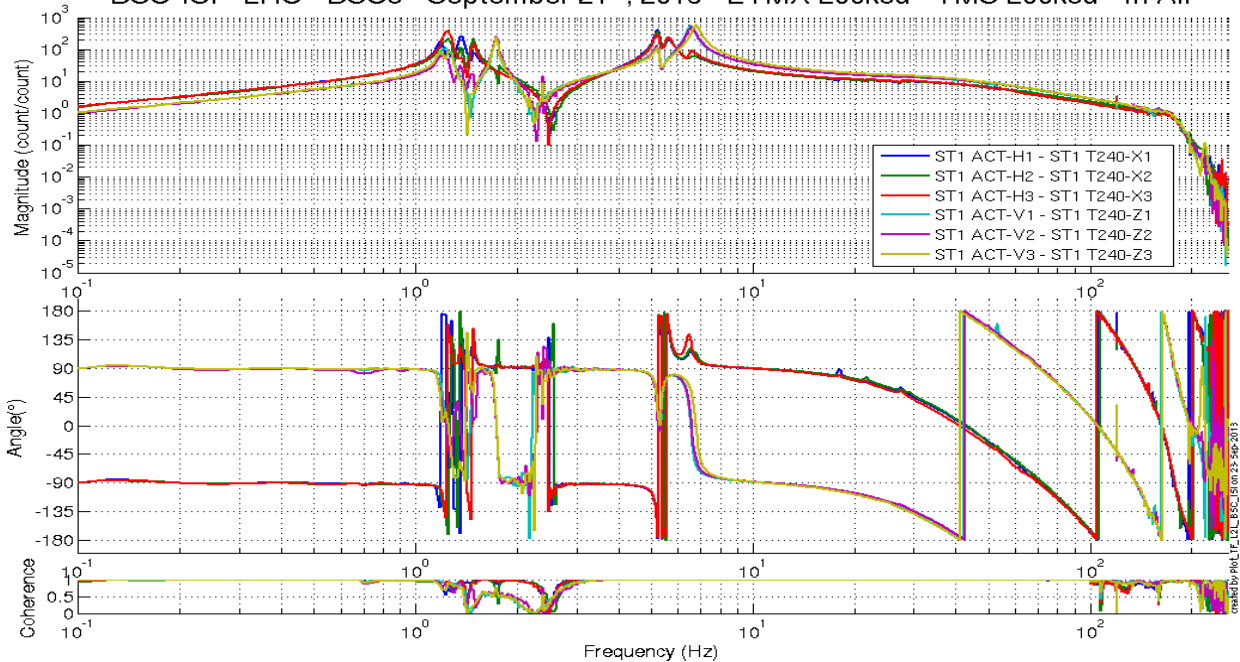


Figure 5 - TF ST1 ACT to ST1 T240

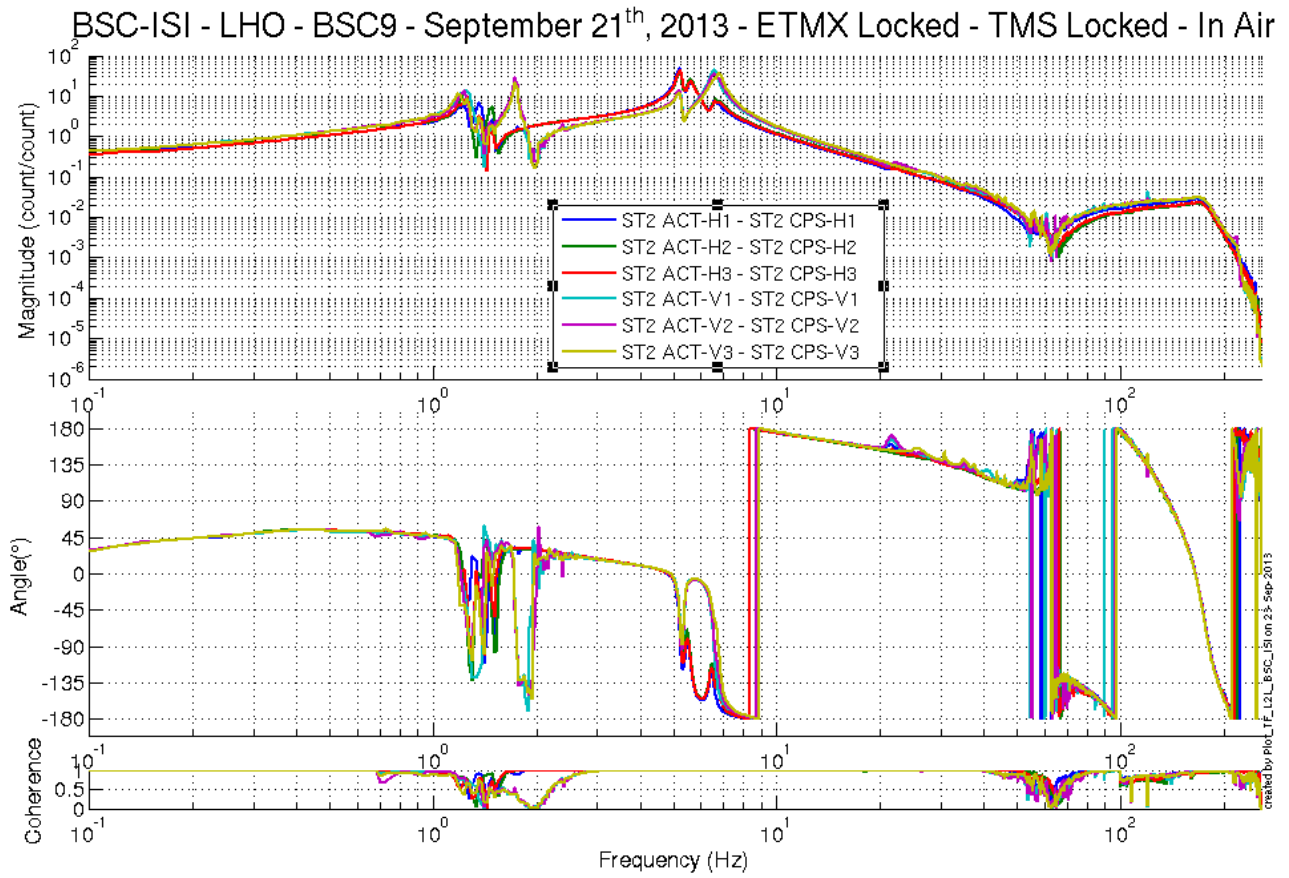


Figure 6 - TF ST2 ACT to ST2 CPS

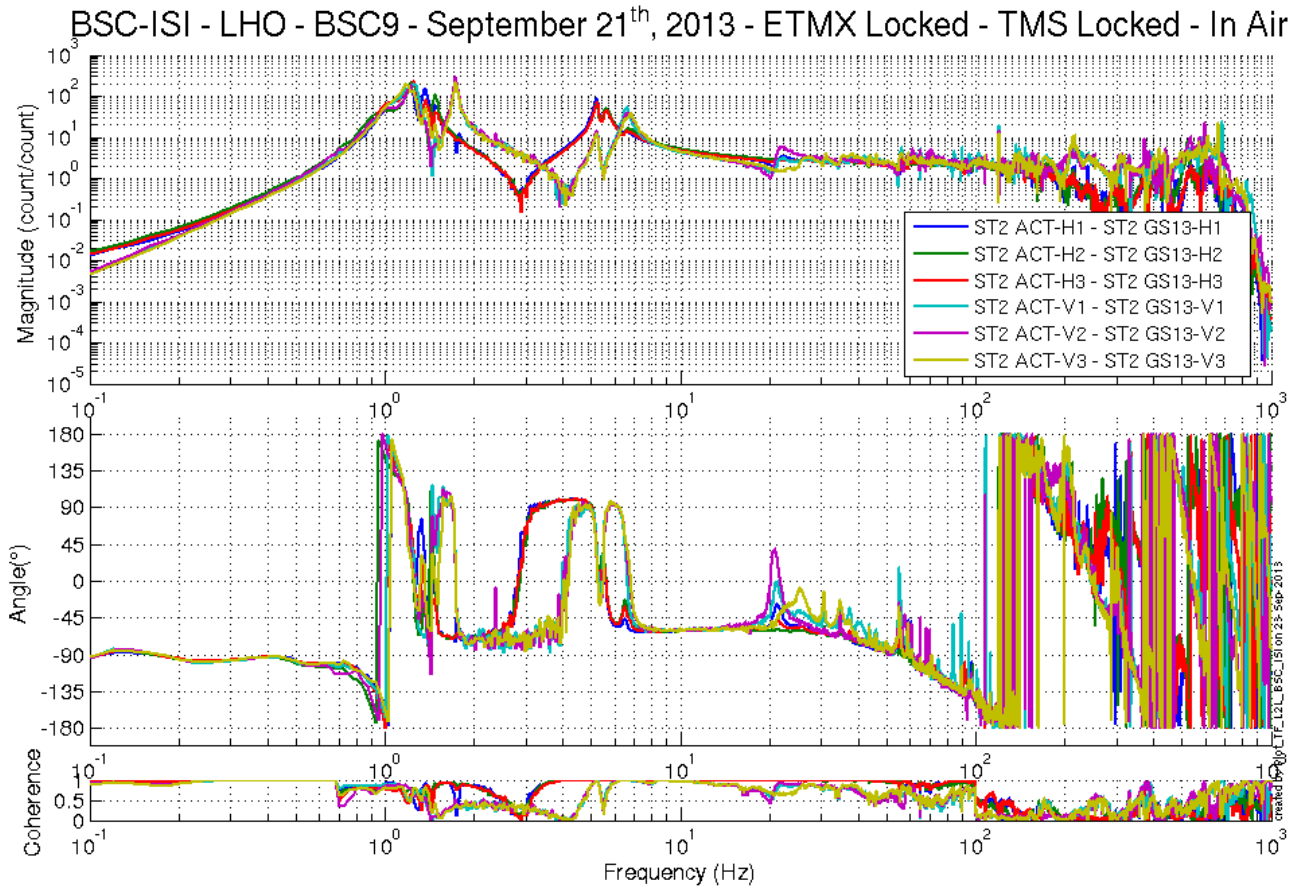


Figure 7 - TF ST2 ACT to ST2 GS13

i. Comparisons with measurements in the staging building

The script used to compare transfer function can be found in the SVN at:

SeiSVN/seismic/BSC-ISI/H1/ETMX/Scripts/Misc

- [Comparison TF L2L H1 ISI ETMX.m](#)

The figure that shows the comparison between the transfer functions of the staging building and the LVEA are located in the SVN at:

SeiSVN/seismic/BSC-ISI/H1/ETMX/Data/Figures/Transfer_Functions/Measurements/Comparison/L2L/

- [H1 ISI ITMX Comparison TF L2L ST1 ACT H to ST1 CPS H 20130309 vs 20130921.fig](#)
- [H1 ISI ITMX Comparison TF L2L ST1 ACT H to ST1 L4C H 20130309 vs 20130921.fig](#)
- [H1 ISI ITMX Comparison TF L2L ST1 ACT V to ST1 CPS V 20130309 vs 20130921.fig](#)
- [H1 ISI ITMX Comparison TF L2L ST1 ACT V to ST1 L4C V 20130309 vs 20130921.fig](#)
- [H1 ISI ITMX Comparison TF L2L ST2 ACT H to ST2 CPS H 20130309 vs 20130921.fig](#)
- [H1 ISI ITMX Comparison TF L2L ST2 ACT H to ST2 GS13 H 20130309 vs 20130921.fig](#)
- [H1 ISI ITMX Comparison TF L2L ST2 ACT V to ST2 CPS V 20130309 vs 20130921.fig](#)
- [H1 ISI ITMX Comparison TF L2L ST2 ACT V to ST2 GS13 V 20130309 vs 20130921.fig](#)

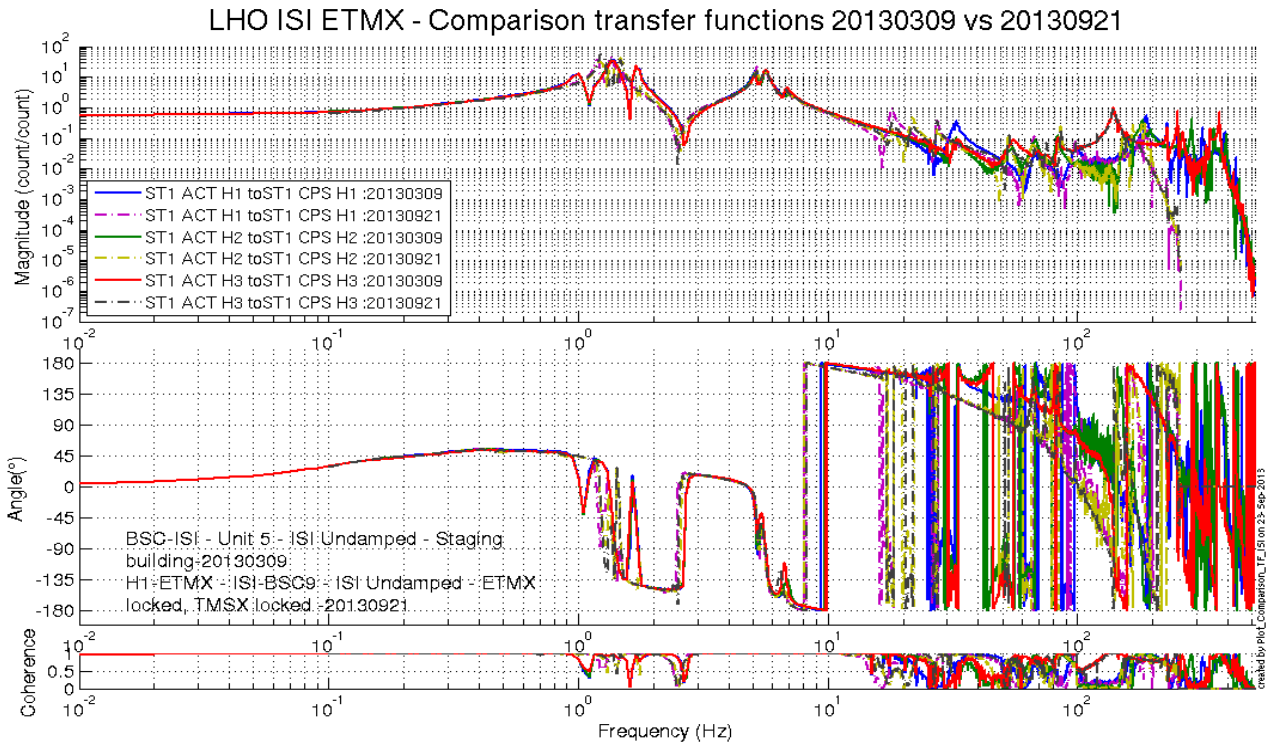


Figure 8 - Transfer functions comparison - ST1 ACT H to ST1 CPS H

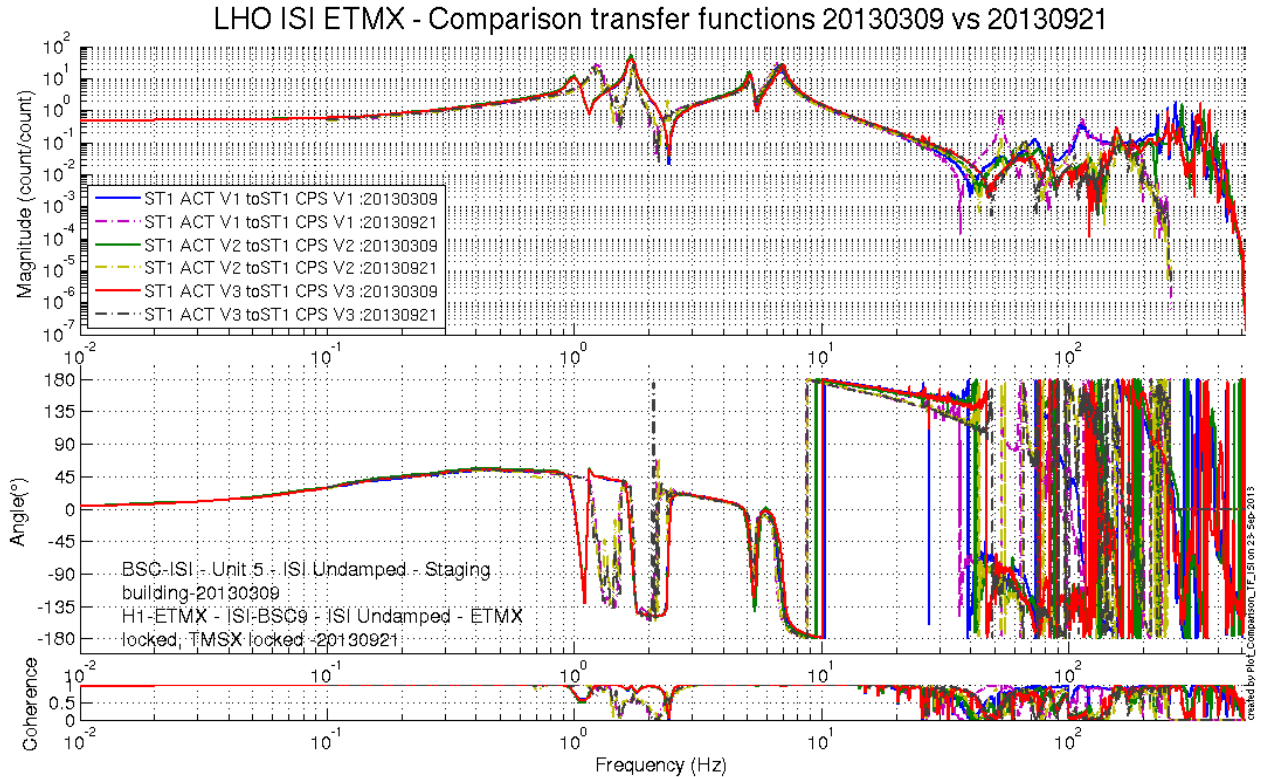


Figure 9 - Transfer functions comparison - ST1 ACT V to ST1 CPS V

LHO ISI ETMX - Comparison transfer functions 20130309 vs 20130921

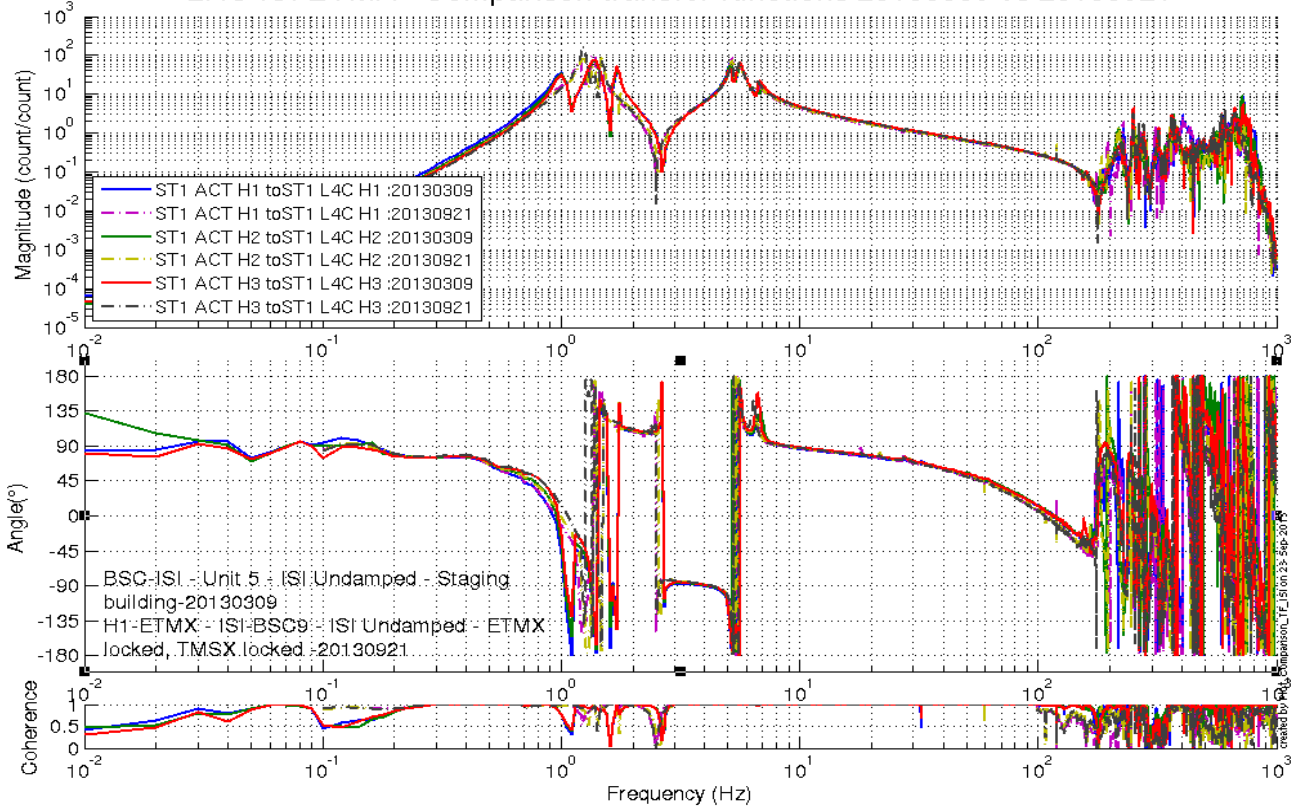


Figure 10 - Transfer functions comparison - ST1 ACT H to ST1 L4C H

LHO ISI ETMX - Comparison transfer functions 20130309 vs 20130921

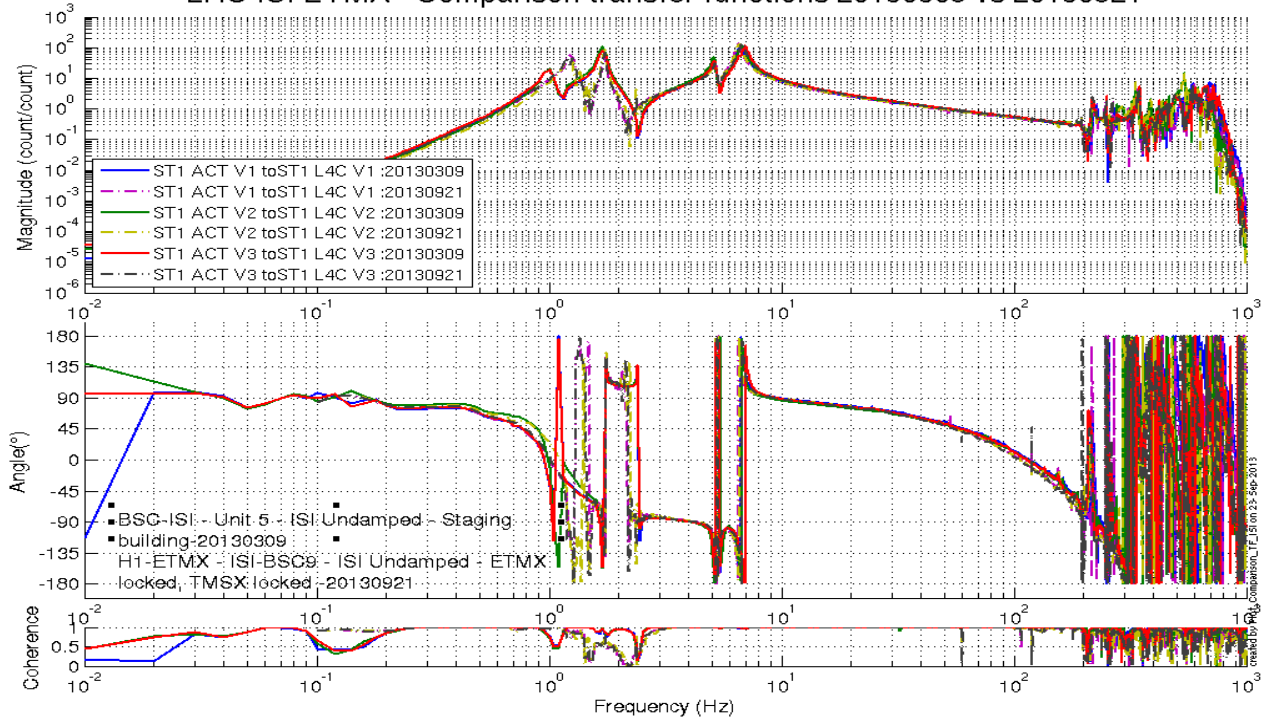


Figure 11 - Transfer functions comparison - ST1 L4C V to ST1 L4C V

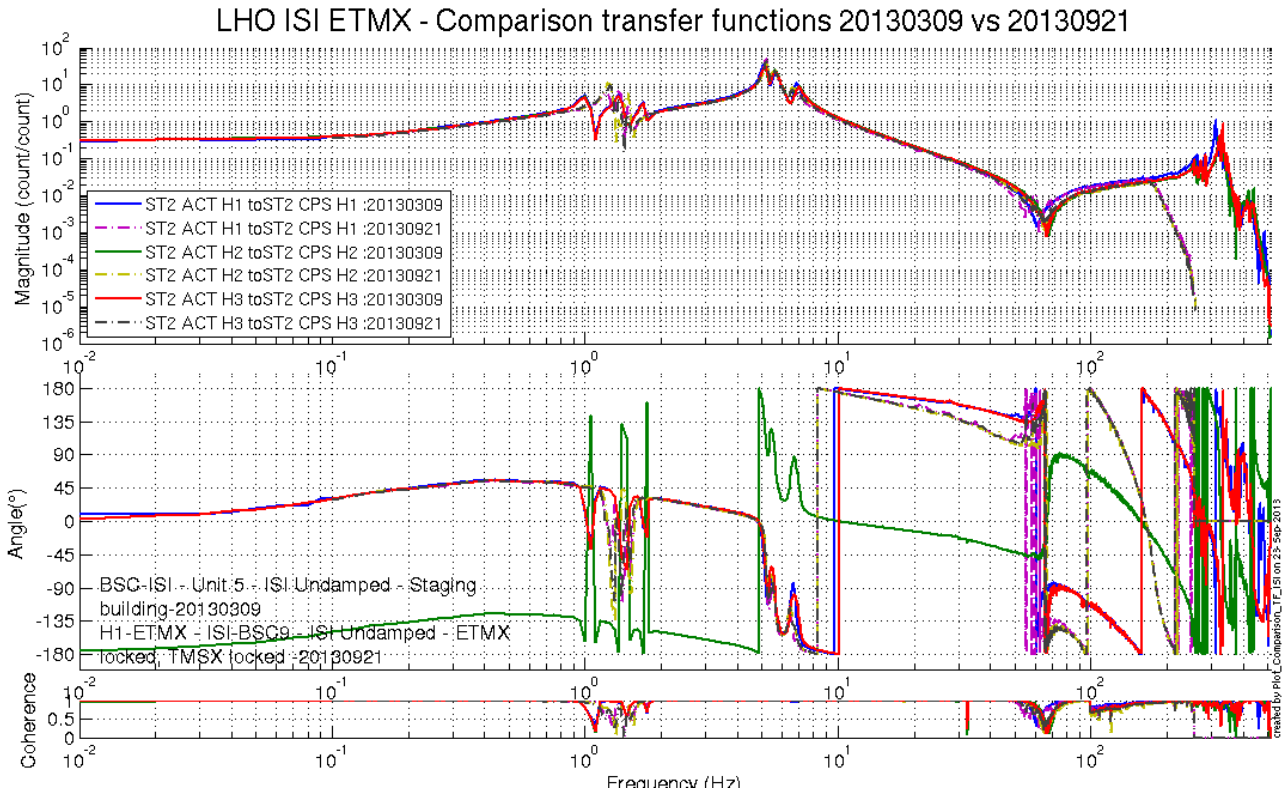


Figure 12 - Transfer functions comparison - ST2 ACT H to ST2 CPS H

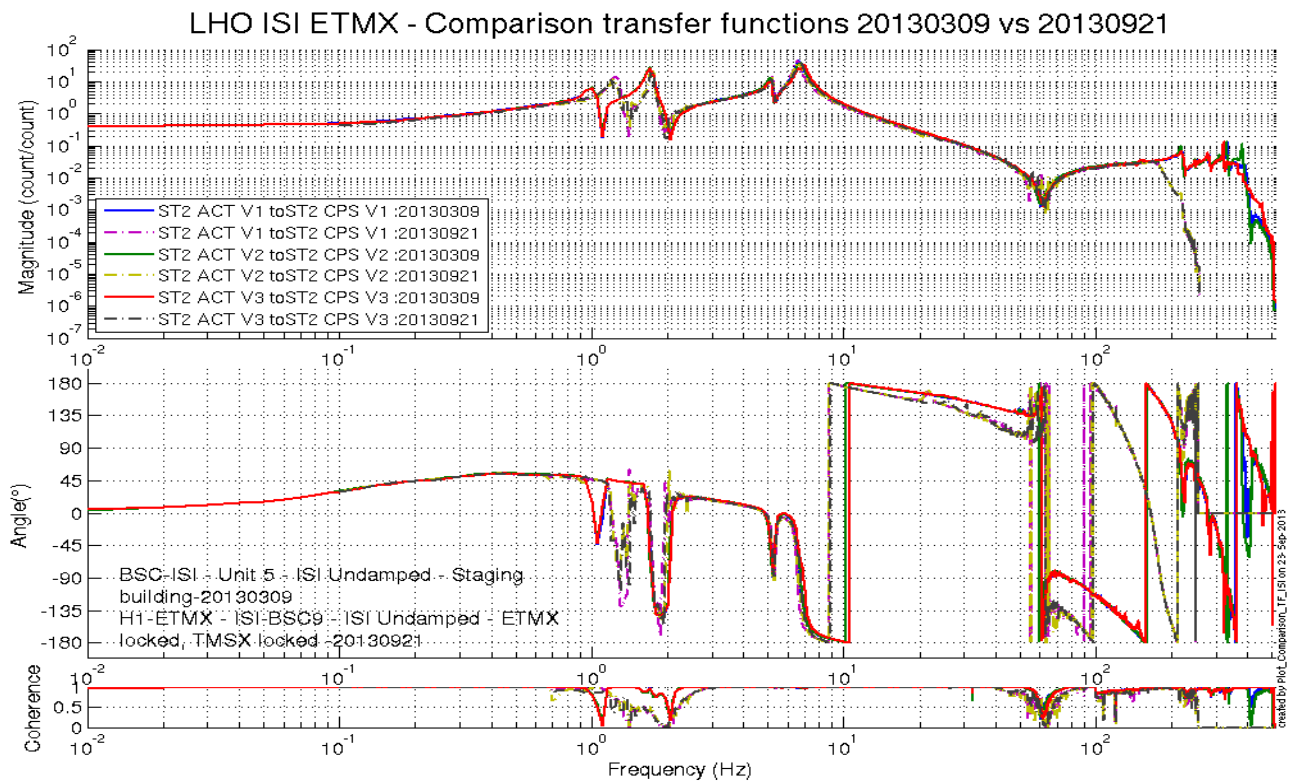


Figure 13 - Transfer functions comparison - ST2 ACT V to ST2 CPS V

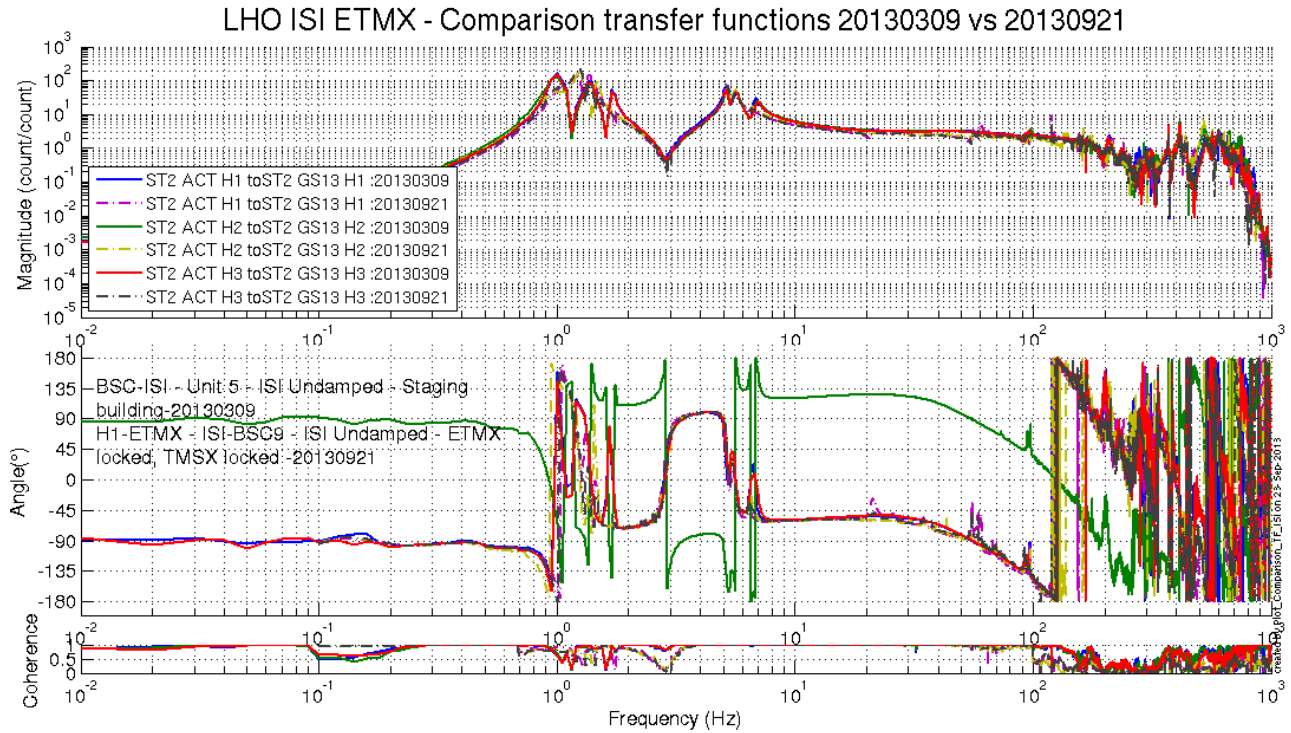


Figure 14 - Transfer functions comparison – ST2 ACT H to ST2 GS13 H

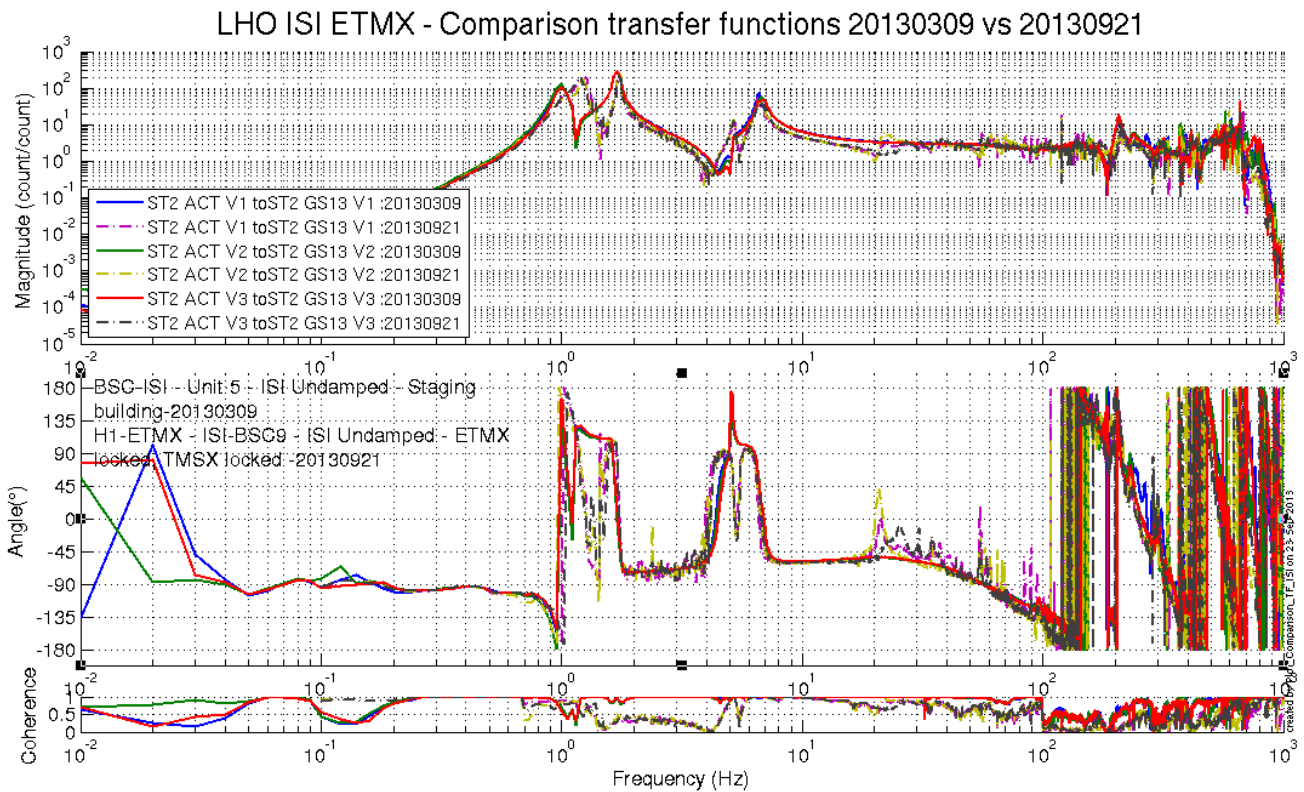


Figure 15 - Transfer functions comparison – ST2 ACT V to ST2 GS13 V

Phase IIb Tests after Cartridge Install

Basic Functionality after Cartridge Installation

1. Pressure Sensors

All pressure sensors are working.

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/H1/ETMX/Data/Static_Tests/LHO_ISI_BSC9_Pressure_Sensors_Check_Calibrated_2012_03_29_115020.mat

Sensors	Pressure (KPa)		
	Corner 1	Corner 2	Corner 3
ST1-L4C-P	99	99	101
ST1-L4C-D	0	.4	-.3
ST1-GS13-P	100	100	102
ST1-GS13-D	.4	.1	1
ST1-T240-P	100	101	101

Table 9 - Geophones Pressure sensors

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

2. Spectra

Spectra of the seismometers can be found in the svn at:

[seismic/BSC-ISI/H1/ETMX/Data/Spectra/Undamped/](https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/H1/ETMX/Data/Spectra/Undamped/)

[H1_ISI_ETMX_ASD_m_LOC_CPS_T240_L4C_GS13_2020_11_04_30:7:.mat](https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/H1/ETMX/Data/Spectra/Undamped/H1_ISI_ETMX_ASD_m_LOC_CPS_T240_L4C_GS13_2020_11_04_30:7:.mat)

https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/H1/ETMX/Data/Figures/Spectra/Undamped/H1_ISI_ETMX_ASD_CT_LOC_CPS_T240_L4C_GS13_2020_11_03_33:8:.fig

[H1_ISI_ETMX_ASD_CT_LOC_CPS_T240_L4C_GS13_2020_11_03_33:8:.fig](https://svn.ligo.caltech.edu/svn/seismic/BSC-ISI/H1/ETMX/Data/Figures/Spectra/Undamped/H1_ISI_ETMX_ASD_CT_LOC_CPS_T240_L4C_GS13_2020_11_03_33:8:.fig)

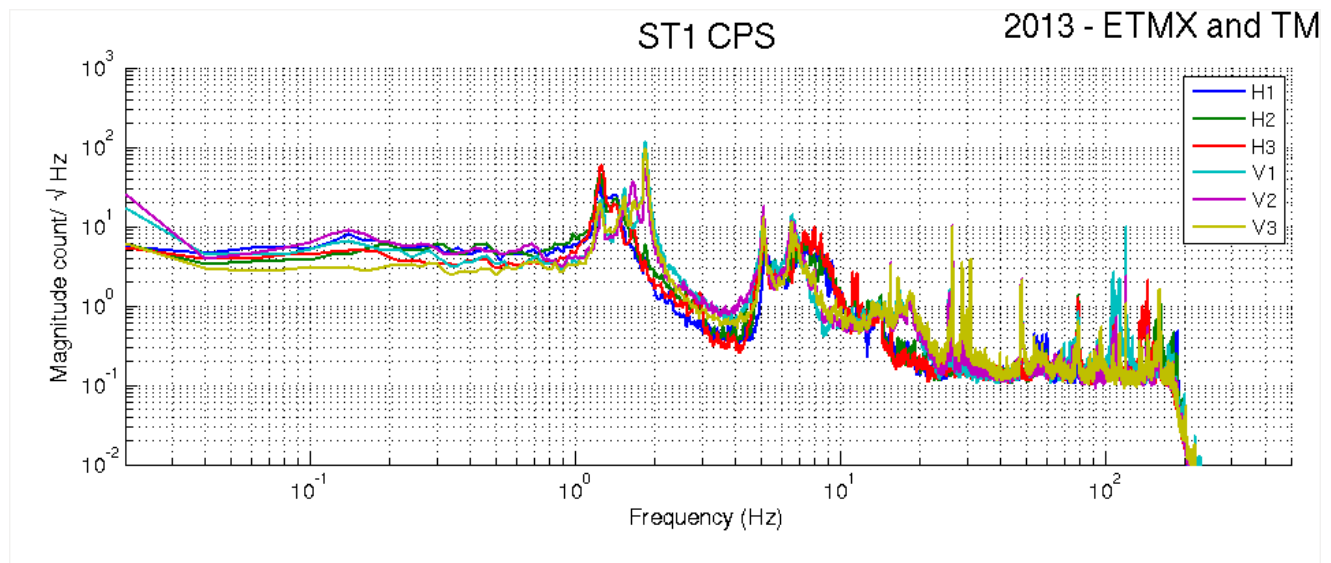


Figure 16 - St1 CPS Power Spectra

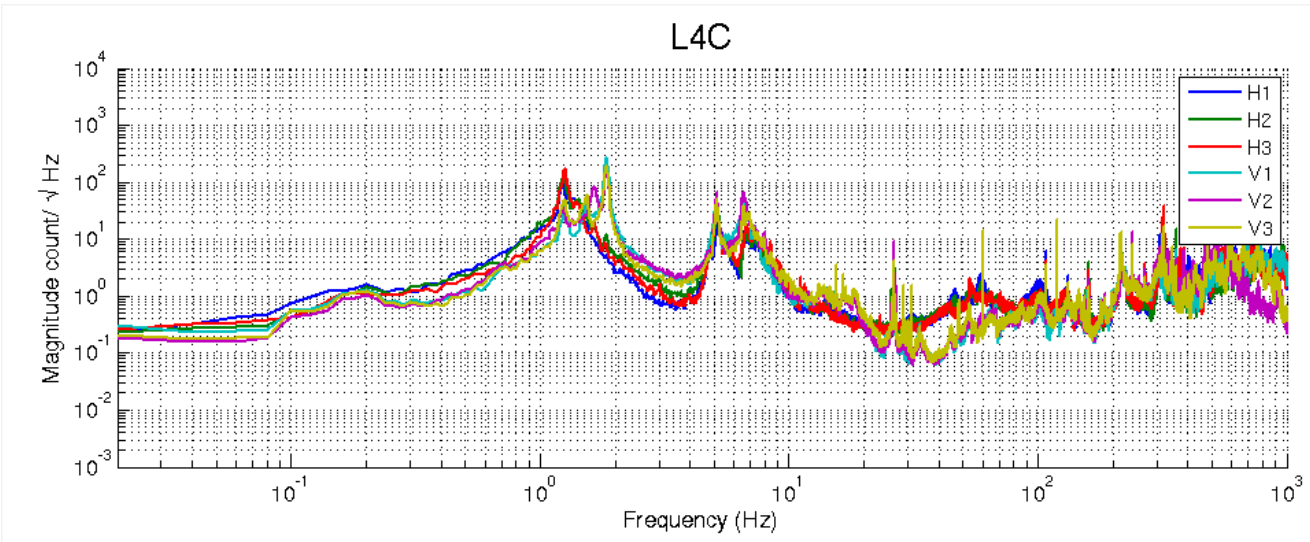


Figure 17 - St1 L4C Power Spectra

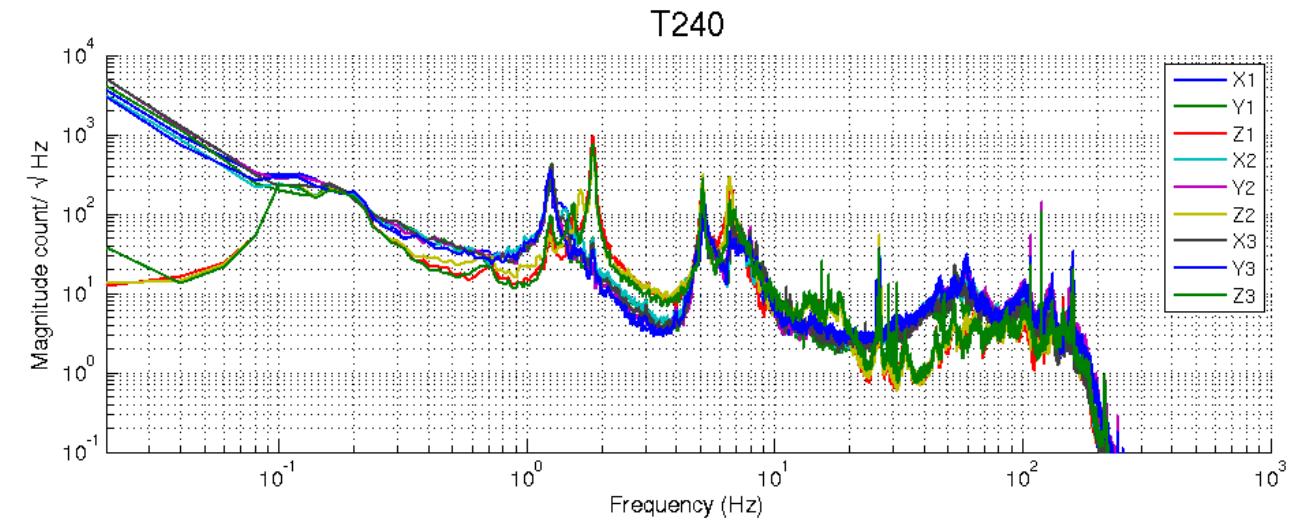


Figure 18 - St1 L4C Power Spectra

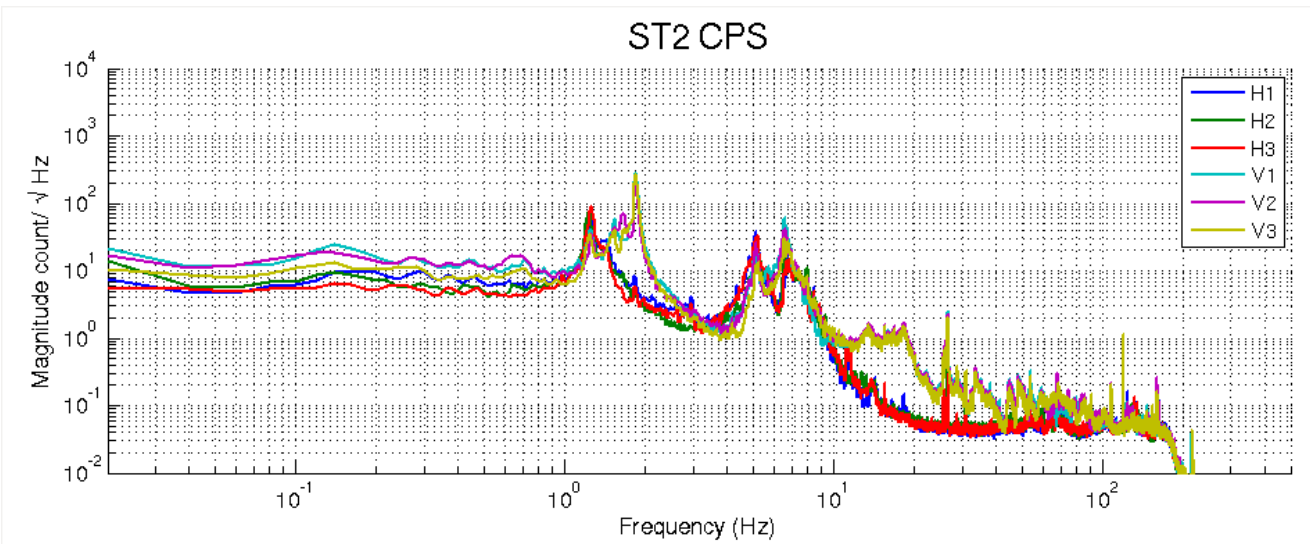


Figure 19 - St2 CPS Power Spectra

3. Lock Unlock Shifts

Sensors	Table locked		Table unlocked		Difference locked - unlocked	
	Offset (Mean)	Std deviation	Offset (Mean)	Std deviation	Offset (Mean)	mil
ST1 - H1	1071.8	481.45	330.59	14.904	741	0.88
ST1 - H2	512.11	-13.629	-27.803	13.951	540	0.64
ST1 - H3	-9.5435	-49.222	81.613	14.808	-91	-0.11
ST1 - V1	-371.33	-26.101	70.692	19.531	-442	-0.53
ST1 - V2	440.52	175.56	65.529	14.535	375	0.45
ST1 - V3	-36.746	-458.62	-1426.3	17.086	1390	1.65
ST2 - H1	1460.9	425.38	270.42	29.013	1190	0.35
ST2 - H2	2037.6	45.322	-766.2	22.741	2804	0.83
ST2 - H3	373.38	-1446.7	-2342.8	27.023	2716	0.81
ST2 - V1	-621.02	-829.97	29.083	50.889	-650	-0.19
ST2 - V2	153.88	394.46	9.421	38.4	144	0.04
ST2 - V3	1145.4	166.79	-740.37	40.959	1886	0.56

Table 10 - Lock/Unlock Shifts.

Locker shifts are within spec.

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

4. Range of motion

Sensor readout (counts)	Negative drive	no drive	Positive drive	Amplitude count	mil
ST1 - H1	-15370.684	303	16428.194	31799	38
ST1 - H2	-15722.058	-70	16133.428	31855	38
ST1 - H3	-16100.496	72	15531.054	31632	38
ST1 - V1	-13136.432	94	13348.358	26485	32
ST1 - V2	-13249.552	46	13352.212	26602	32
ST1 - V3	-14762.886	-1357	11966.032	26729	32
ST2 - H1	-9406.8736	260	9889.9792	19297	6
ST2 - H2	-10307.194	-814	8695.1964	19002	6
ST2 - H3	-11866.872	-2371	7111.8122	18979	6
ST2 - V1	-11508.06	165	11731.846	23240	7
ST2 - V2	-11388.044	81	11559.116	22947	7
ST2 - V3	-12074.618	-544	10864.158	22939	7

Table 11 - Range of motion under actuator drive

Range of motion is within spec.

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

5. CPS Linearity Test

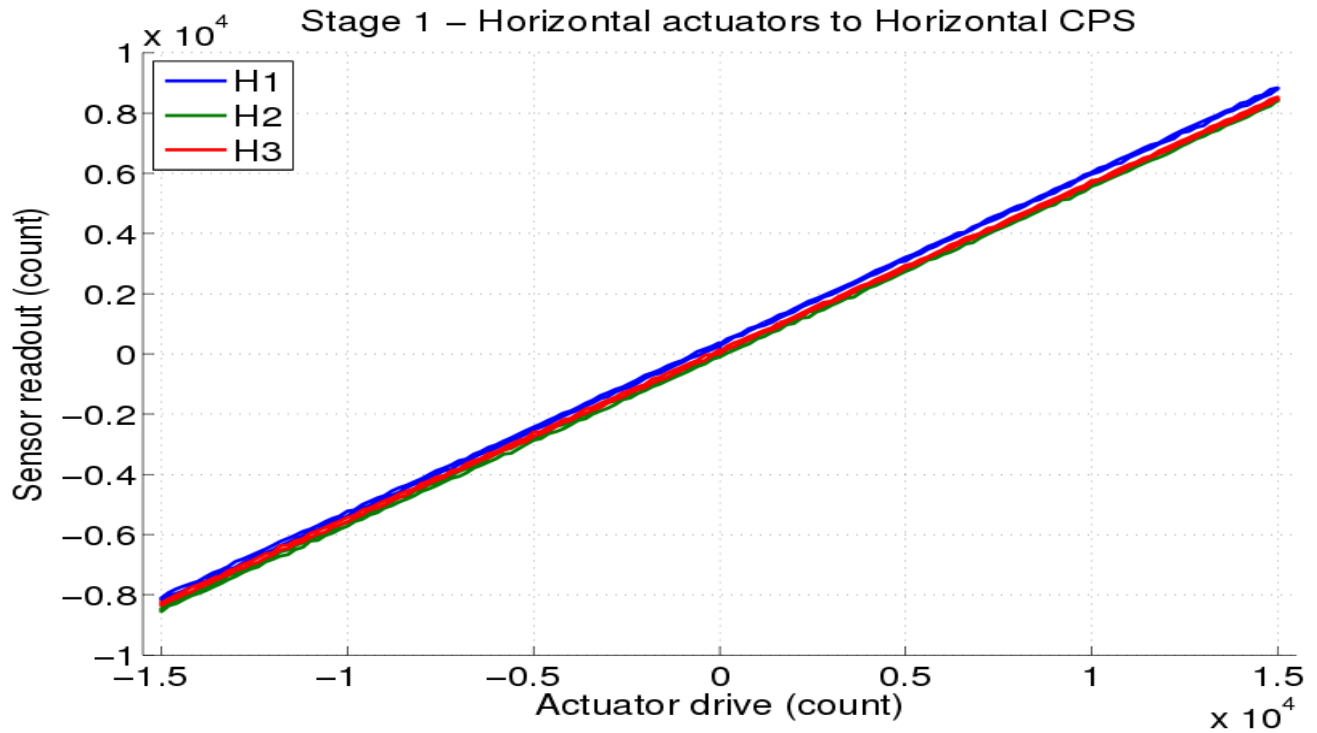


Figure 21 St1 Horizontal Sensor

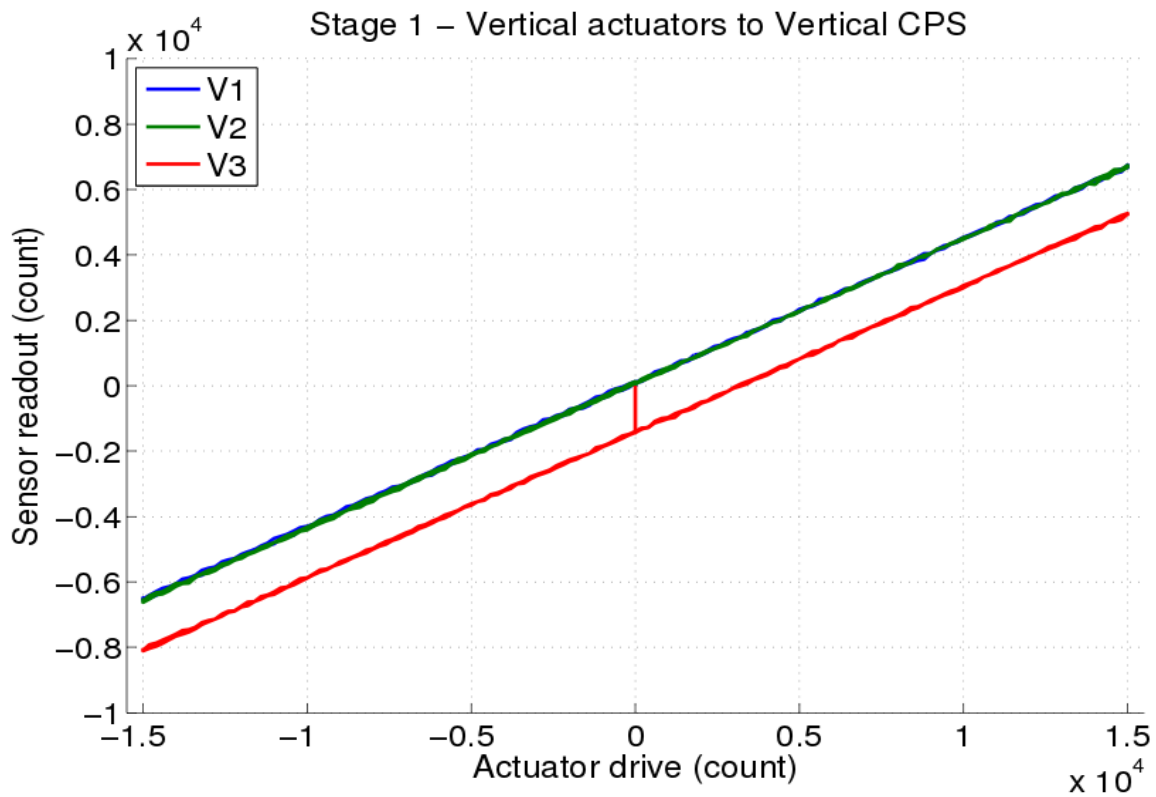


Figure 22 St1 Vertical

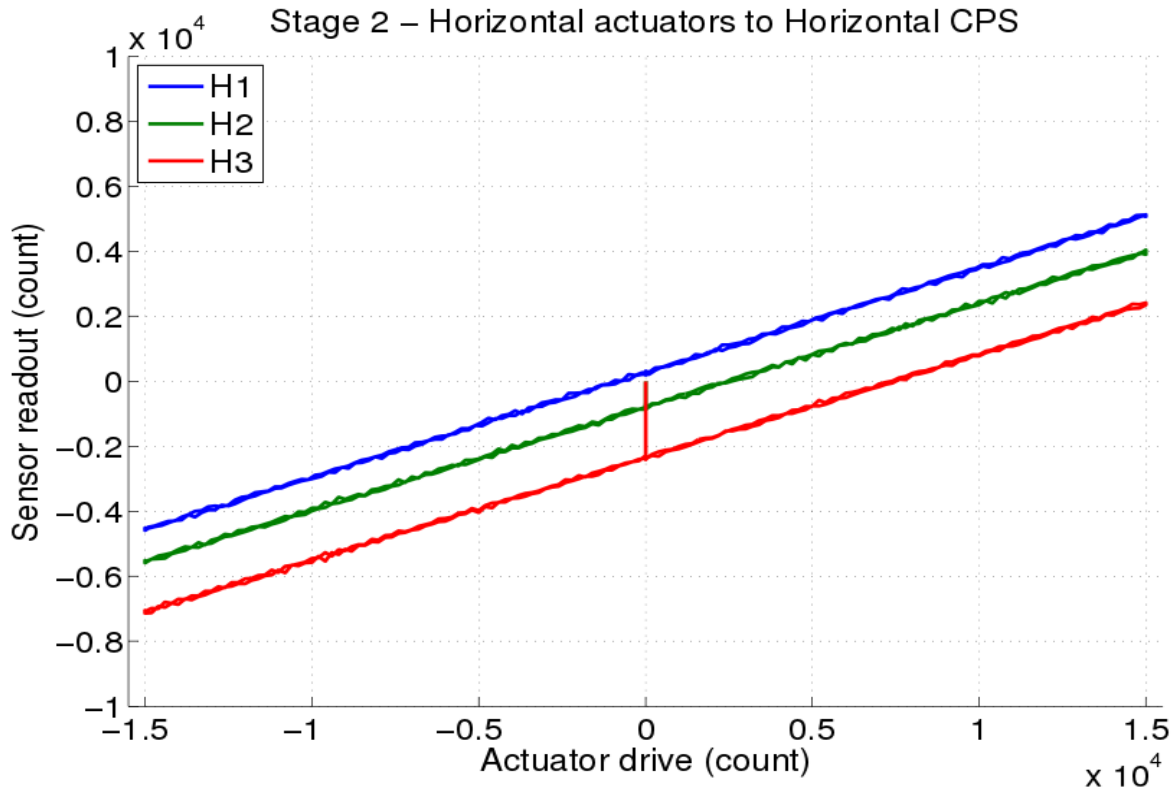


Figure 23 Stage 2 Horizontal

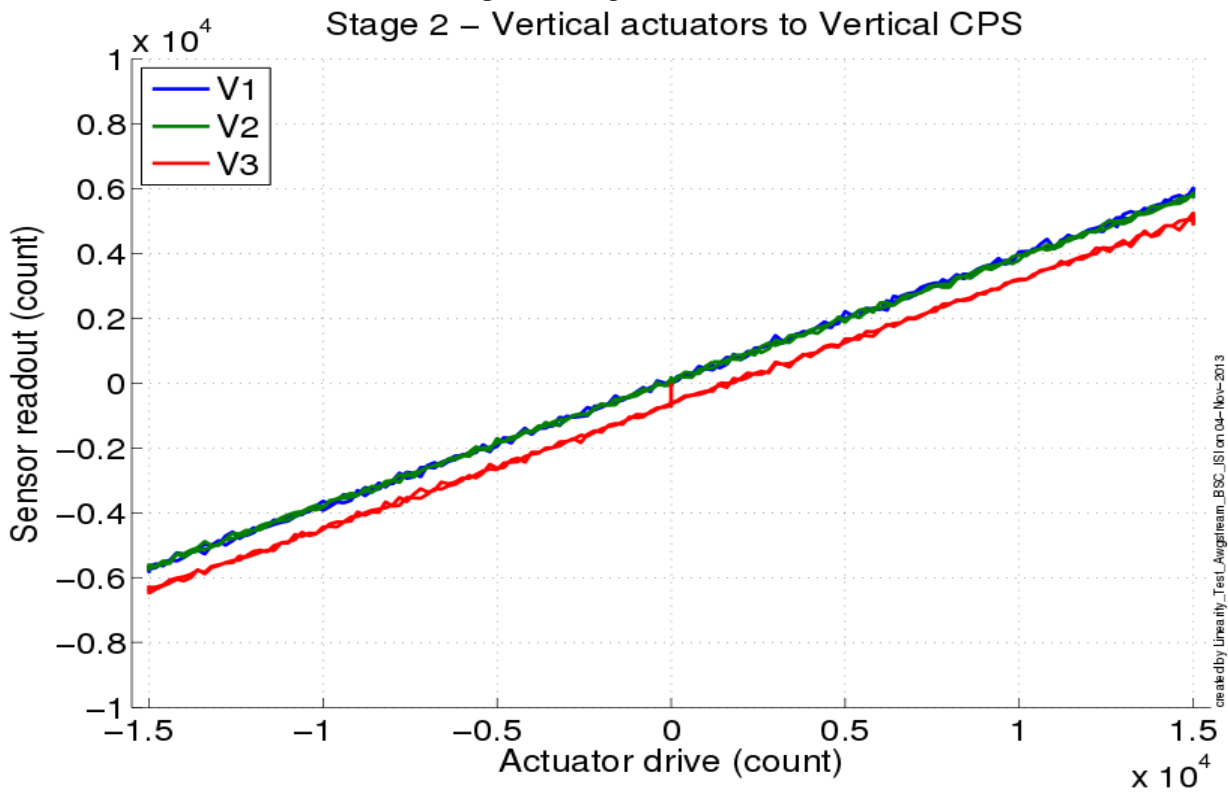


Figure 24 Stage 2 Vertical



CPS linearity is within spec.

Test result:

Passed: X

Failed:

Waived:



		Slope	Offset	Average slope	Variation (%)
Stage 1	ST1 - H1	.564	337	.562	.5
	ST1 - H2	.562	-33		.06
	ST1 - H3	.559	88		-.56
	ST1 - V1	.440	97	.443	-.51
	ST1 - V2	.442	73		-.05
	ST1 - V3	.445	-1408		.56
Stage 2	ST2 - H1	.322	265	.319	.98
	ST2 - H2	.318	-782		-.27
	ST2 - H3	.317	-2333		-.71
	ST2 - V1	.386	70	.384	.56
	ST2 - V2	.382	56		-.42
	ST2 - V3	.384	-650		-.14

Table 12 - Slope – Offset Linearity test

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

2. Transfer Functions after Cartridge Install

Reference transfer functions L2L with ETMX, TMSX, ACB and all ISI viton damping elements.

Transfer Functions are located in the SVN at:

```

/SeiSVN/seismic/BSC-ISI/H1/ETMX/Data/Transfer_Functions//Undamped/
-H1_ISI_ETMX_Data_L2L_700mHz_10Hz_ST1_ST2_20131101-164416.mat
-H1_ISI_ETMX_Data_L2L_10Hz_100Hz_ST1_ST2_20131101-222314.mat
-H1_ISI_ETMX_Data_L2L_100Hz_500Hz_ST1_ST2_20131104-103756.mat
-H1_ISI_ETMX_Data_L2L_500Hz_1000Hz_ST1_ST2_20131104-124252.mat

```

L2L concatenated

```

/SeiSVN/seismic/BSC-ISI/H1/ETMX/Data/Transfer_Functions/Simulations/Undamped/
-H1_ISI_ETMX_TF_L2L_Raw_2013_11_04.mat

```

BSC-ISI - LHO - BSC9 - Nov 5th, 2013 - ETMX unLocked more damping - TMS unLocked more damping

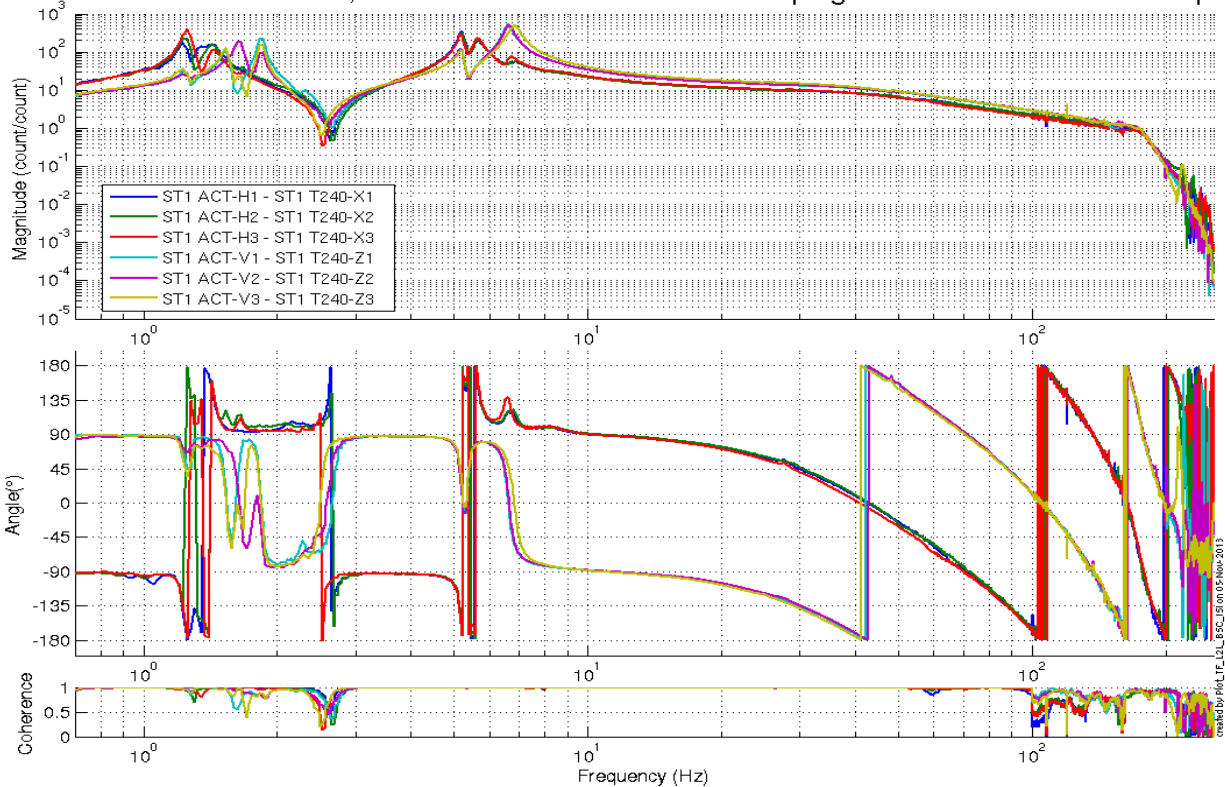


Figure 25 St1 Act to T240

BSC-ISI - LHO - BSC9 - Nov 5th, 2013 - ETMX unLocked more damping - TMS unLocked more damping

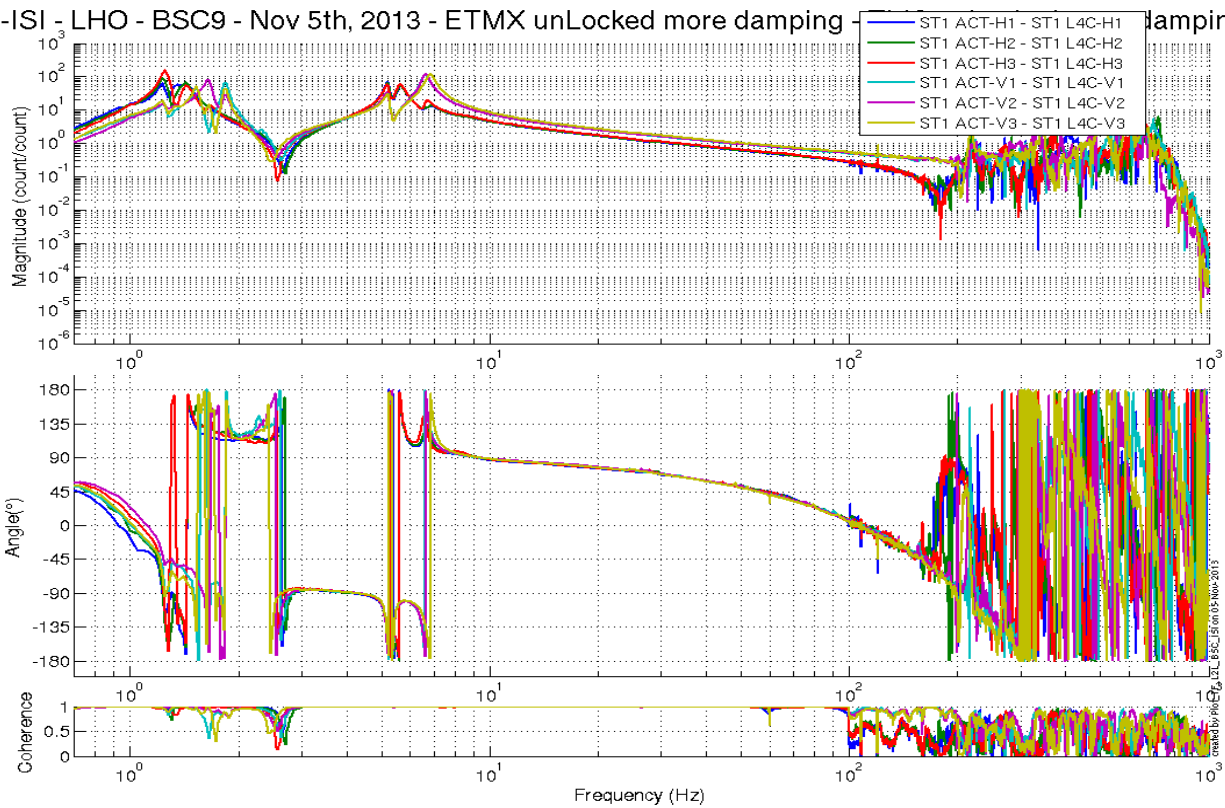


Figure 26 St1 Act to L4C

BSC-ISI - LHO - BSC9 - Nov 5th, 2013 - ETMX unLocked more damping - TMS unLocked more damping

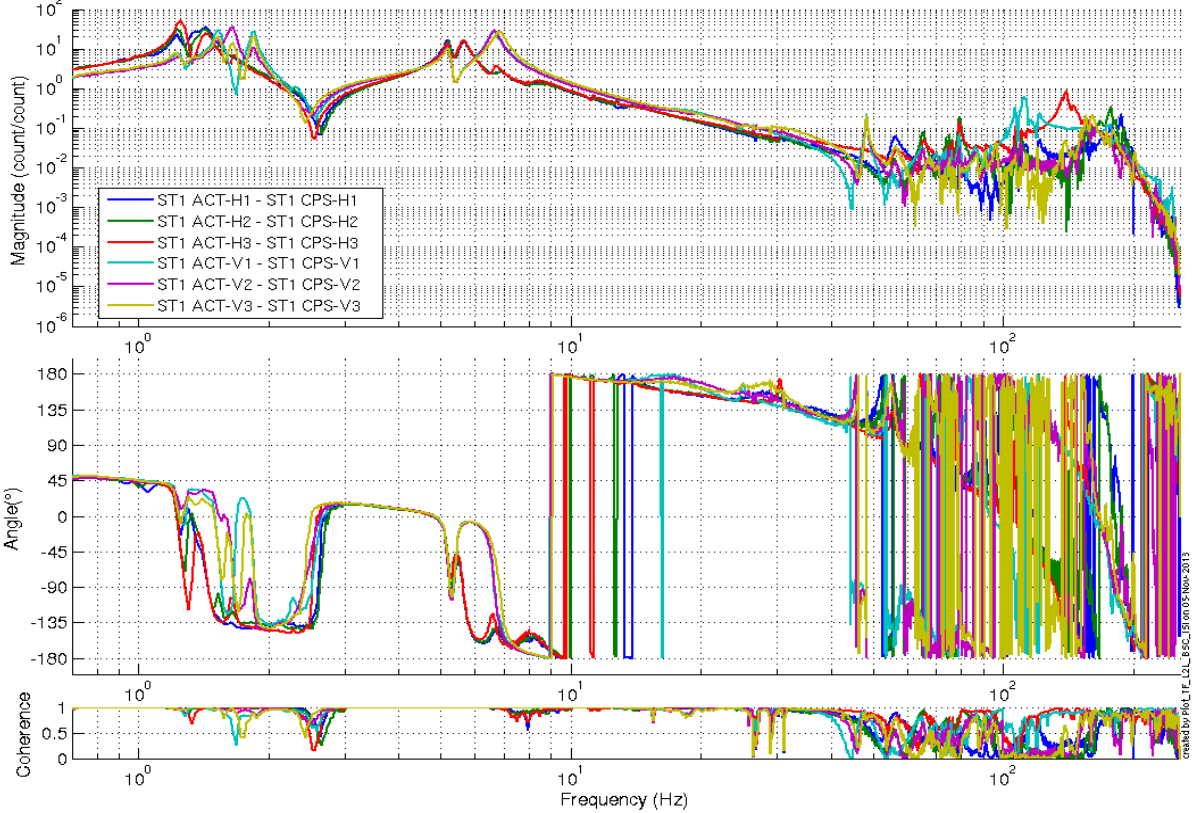


Figure 27 St1 Act to St1 CPS

BSC-ISI - LHO - BSC9 - Nov 5th, 2013 - ETMX unLocked more damping - TMS unLocked more damping

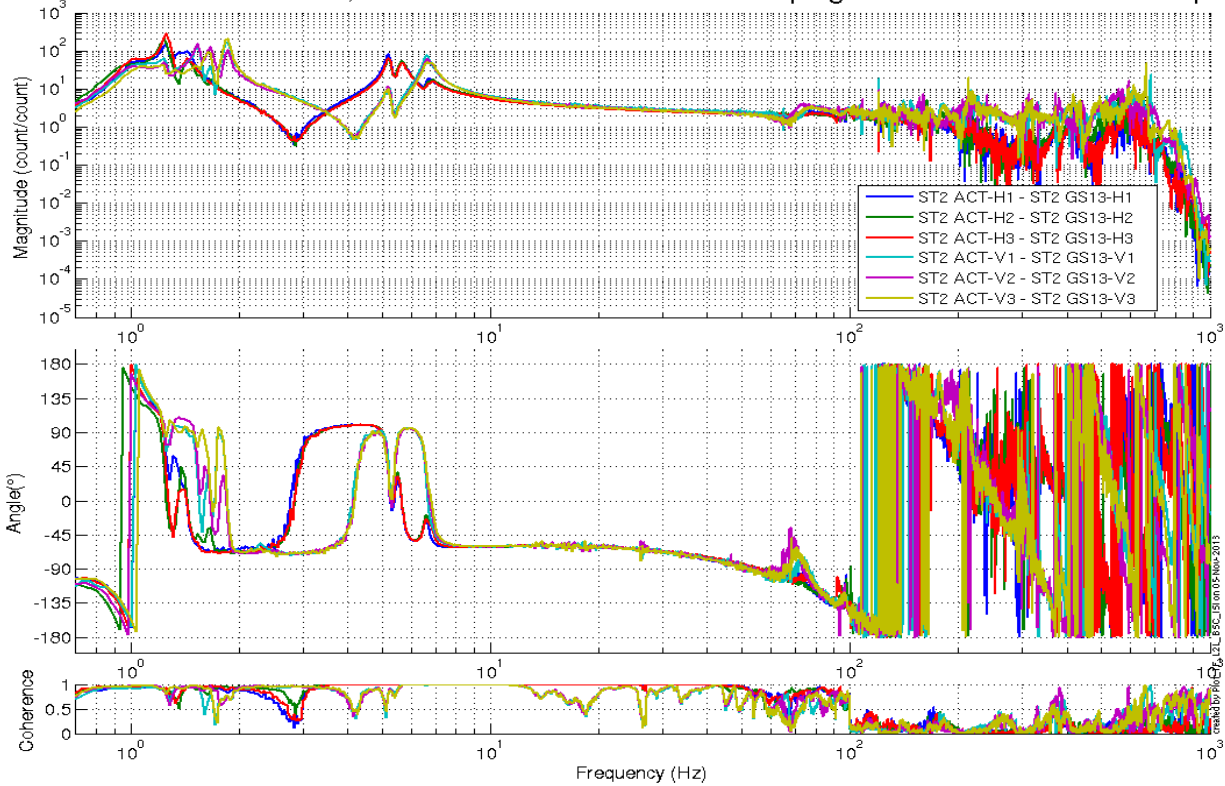


Figure 28 St2 Act to GS13

BSC-ISI - LHO - BSC9 - Nov 5th, 2013 - ETMX unLocked more damping - TMS unLocked more damping

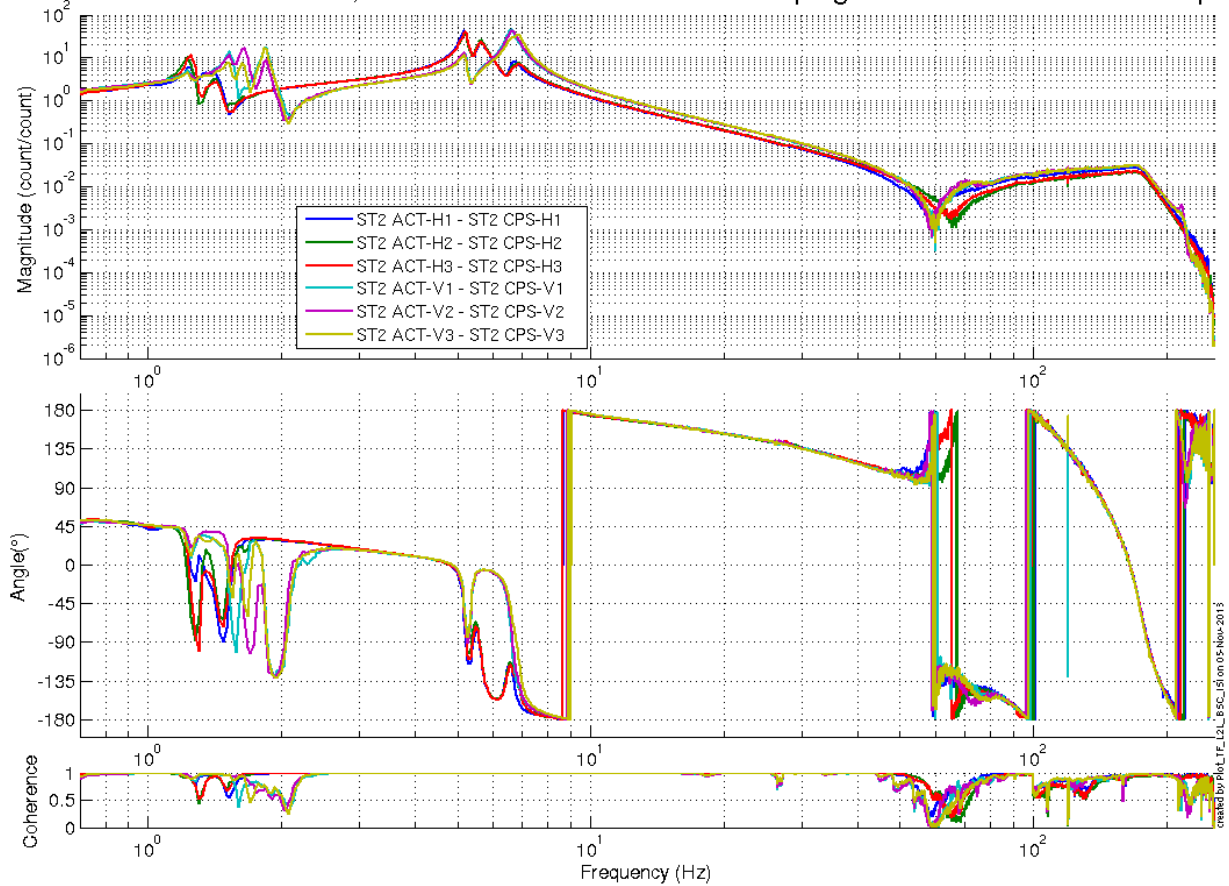


Figure 29 St2 Act to St2 CPS

Transfer functions look healthy.

Test result: Passed: X Failed: Waived:

3. Conclusion Phase II-b

Tests performed during Phase II-b don't show any anomalies on ISI-BSC9.

Test result: Passed: X Failed: Waived: