



*LIGO Laboratory / LIGO Scientific Collaboration*

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*ADVANCED LIGO*

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HAUX H1-IM4 test report

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LIGO Science Collaboration

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## 1 Introduction

This document summarizes the results of tests conducted to verify L1 HAM Auxiliary suspensions' compliance with requirements, as well as other useful information.

### 1.1 Suspension data

*IFO:* L1

*Suspension name:* IM4

*Suspension SN:* 002

*Installed optics:* SM2-03

*UL OSEM SN:* 274

*LL OSEM SN:* 479

*UR OSEM SN:* 255

*LR OSEM SN:* 448

<https://ics-redux.ligo-la.caltech.edu/JIRA/browse/ASSY-D1000120-004>

### 1.2 Applicable Documents

#### 1.2.1 LIGO Documents

[LIGO-T1200469](#), "HAUX test procedure and acceptance criteria"

## 2 Summary of tests

The following table helps to quickly identify in which condition the results of the tests reported in this document refer to.

Gray cells represent the minimum required condition for final testing. “X” indicates the conditions of the test which results are reported in this document.

	Table		Electronics		Cables		Pressure		Result
	Test	HAM	Test	Final	Test	Final	Air	Vac	
<b>OSEMs OLV</b>		X		X		X	X		Passed
<b>DC pointing</b>	X		X		X		X		Passed
<b>OSEMs calibr.</b>	X		X		X		X		Passed
<b>PSDs, no ECDs</b>	X			X	X		X		Passed
<b>TFs, no ECDs</b>	X			X	X		X		Passed
<b>PSDs, with ECDs</b>		X		X		X	X		Passed
<b>TFs, with ECDs</b>		X		X		X	X		Passed
<b>Q measurements</b>									<b>Pending</b>
<b>B&amp;K Hammering</b>		X					X		Passed

### 3 Tests results

#### 3.1 OSEMs OLV

These measurements are the one in use as of 03-Jul-2013, based on measurements performed on HAM table with final electronics and cables.

	UL Channel	LL Channel	UR Channel	LR Channel
UL OSEM	27326			
LL OSEM		19536		
UR OSEM			21340	
LR OSEM				21450

Requirements (from [T1200469](#), § 2.2.4):

- >25k optimal, >20K acceptable

**Passed**

#### 3.2 DC Pointing

This has been measured and corrected chamber-side in date 22-Jun-2012. See LLO aLog [3600](#).

*Measured value:*  $0 \pm 0.5$  mrad

Requirements (from [T1200469](#), § 2.1.1):

- Nominal value (0)  $\pm 1$  mrad

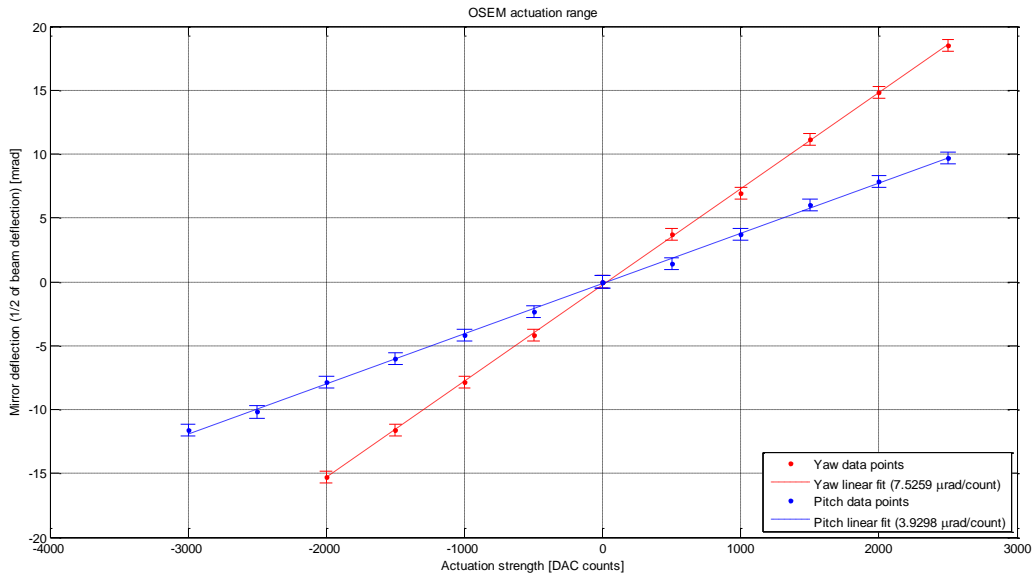
**Passed**

#### 3.3 OSEMs range and linearity

These measurements have been taken in April 2012 with a test setup using production-style electronics, although not the one to be installed in aLIGO). See LLO aLog [2962](#).

Please note: the employed electronics was a preliminary version with different actuation gain from the production units. In addition, during commissioning, proposals have been made to reduce the electronics output gain such that the actuation range of the HAUX would better correspond to what is actually needed (see for example LLO aLog [5213](#)). However, as of the time of writing this document, modifications have not yet been definitively approved or applied to all coil driver boxes and are not considered part of these acceptance tests.

### 3.3.1 Mirror rotation Vs Actuation

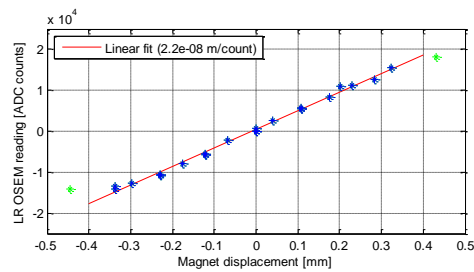
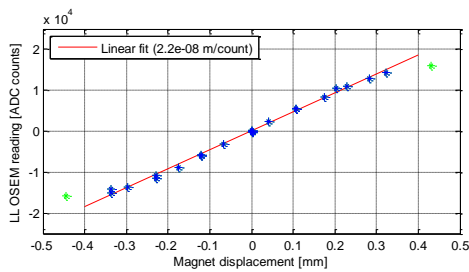
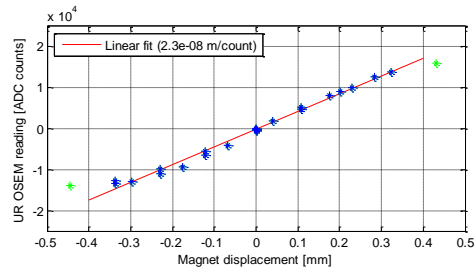
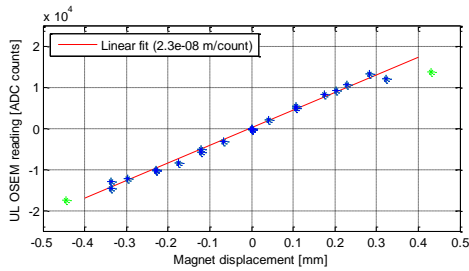


Requirements (from [T1200469](#), § 2.1.1):

- > 10 mrad for full actuation (32000 counts)

**Passed**

### 3.3.2 OSEMs readout Vs Displacement



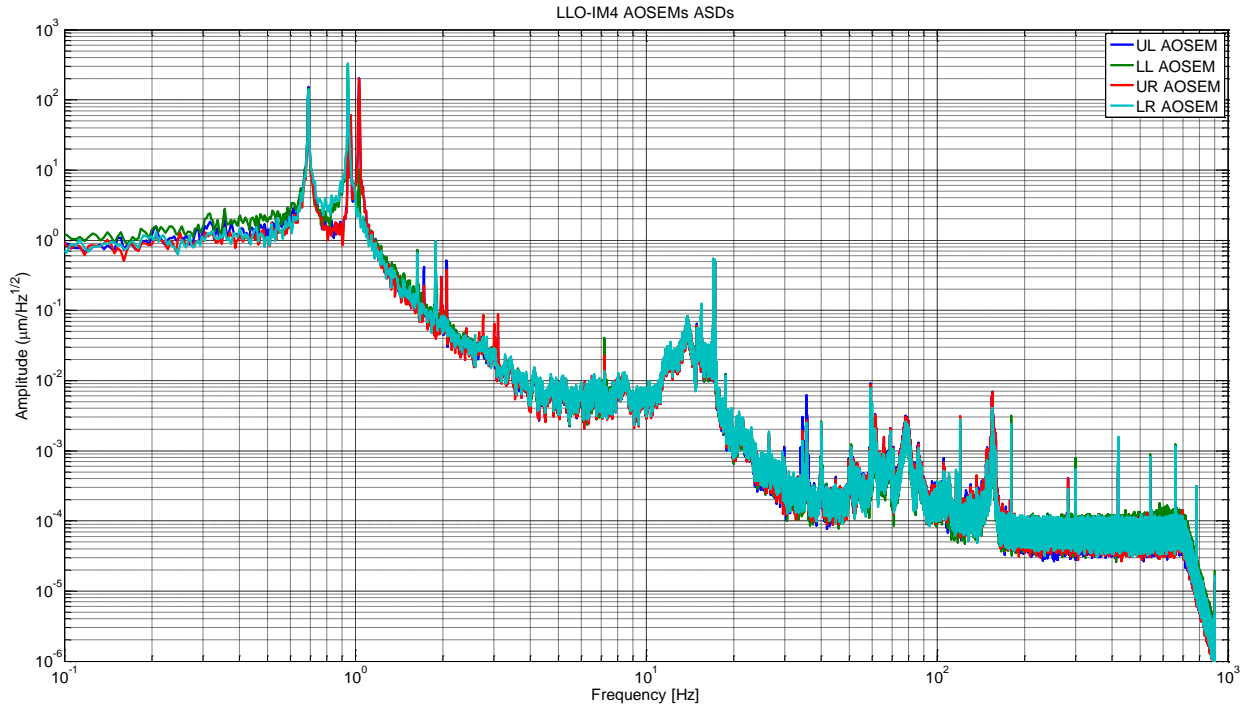
There are no requirements associated with this measurement. It is rather intended to be a sanity check looking for strange (e.g. non linear) behaviors and differences between OSEMs. **Passed**

### 3.4 Linear spectra, no ECDs

These measurements have been taken chamber-side in June 2012.

Data is stored in the SUS SVN repository:

HAUX/L1/Common/dtt\_templates/1024421719\_IM2-IM4\_PSD\_5mHz\_ECDno\_DAMPno.xml



There are no requirements associated with this measurement. It is rather intended to be a sanity check looking for strange behaviors and differences between OSEMs. As a reference, high frequency electronic noise is expect to be  $\sim 10^{-4} \mu\text{m}/\text{Hz}^{1/2}$ . **Passed**

### 3.5 Measured resonances

These have been measured in the LBR in April 2012. See LLO aLog [2962](#).

*Yaw: 0.727 Hz*

*Pitch/Length 1: 0.943 Hz*

*Pitch/Length 2: 1.046 Hz*

*Transverse: 0.998 Hz*

*Bounce: 6.20 Hz*

*Roll: 9.06 Hz*

Requirements (from [T1200469](#), § 2.1.1):

- Pitch, Yaw, Length < 10 Hz (mandatory)
- Transverse, Bounce, Roll < 10 Hz (recommended)

**Passed**

**Passed**

### 3.6 Transfer functions, no ECDs

These measurements have been taken chamber-side in June 2012.

Data is stored in the SUS SVN repository:

HAUX/L1/Common/dtt\_templates/1024948402\_IM2-IM4\_TF-fromY\_20000\_5mHz\_ESDonIM4\_noESDonIM2\_UNDAMPed.xml

HAUX/L1/Common/dtt\_templates/1024951652\_IM2-IM4\_TF-fromP\_10000\_5mHz\_noESD\_UNDAMPed.xml

HAUX/L1/Common/dtt\_templates/1024955187\_IM2-IM4\_TF-fromL\_100000\_5mHz\_noESD\_NODAMPing.xml

Please note:

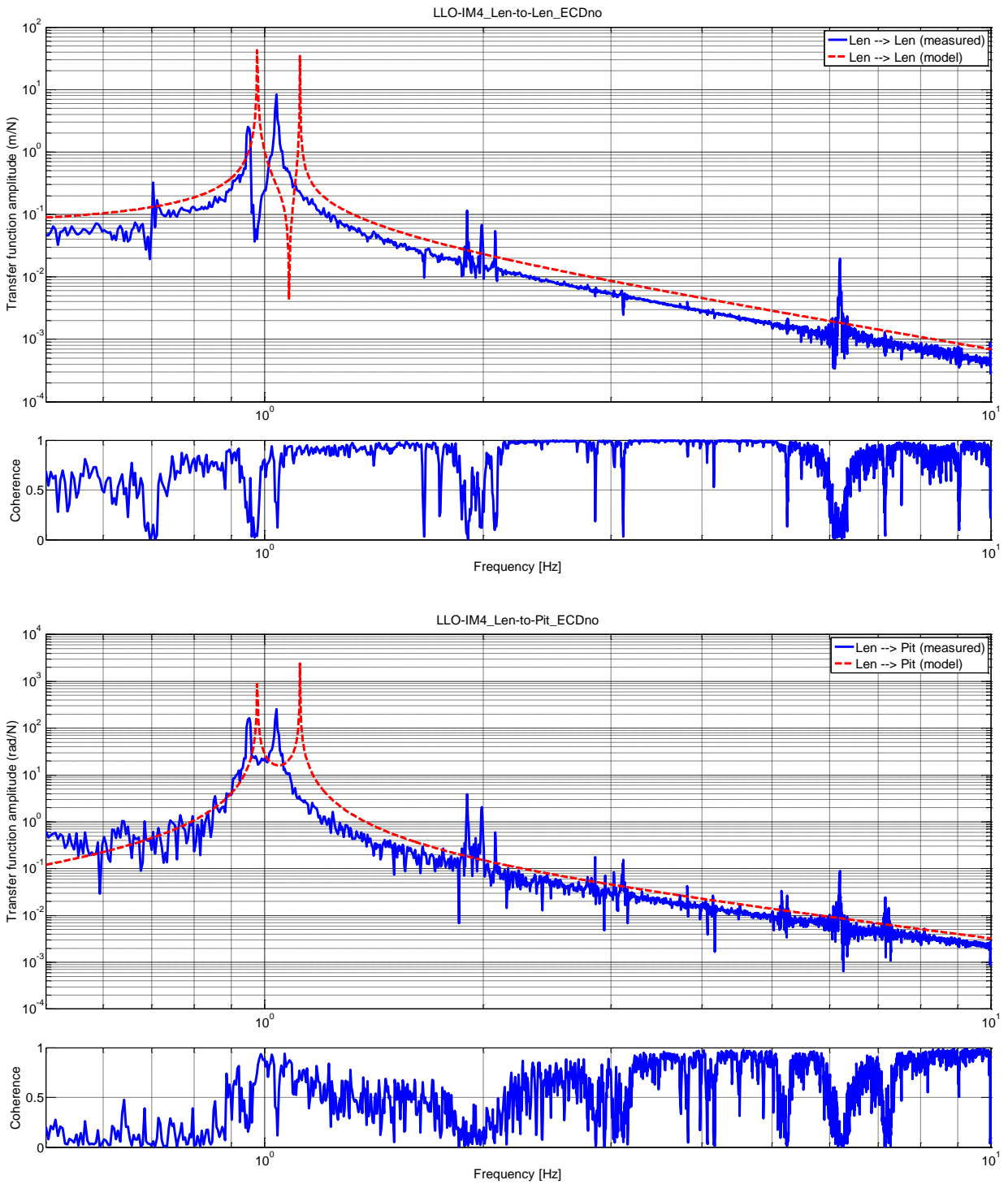
- Proper diagonalization of AOSEMs actuation and readout had not been performed at this stage; thus, cross-coupling between different DoF is visible.
- The “model” curve represents the TF obtained from the Mathematica model using nominal values for all parameters.
- Due to the small weight of the HAUX optics and the need to perform testing in a clean environment under flowing filtered air, many TFs are affected by a comparatively high level of noise.

There is no quantitative requirement associated with this measurement. TFs are expected to be consistent with the model (see, [T1200469](#), § 2.1.5), although close matching of resonances is not necessarily expected.

In general, all resonances appear to be lower than predicted by the model. This is common to all HAUX instances and does not pose a problem from a performance point of view. The TFs are considered acceptable as long as they do not show abnormal behaviors that can suggest rubbing or similar problems.



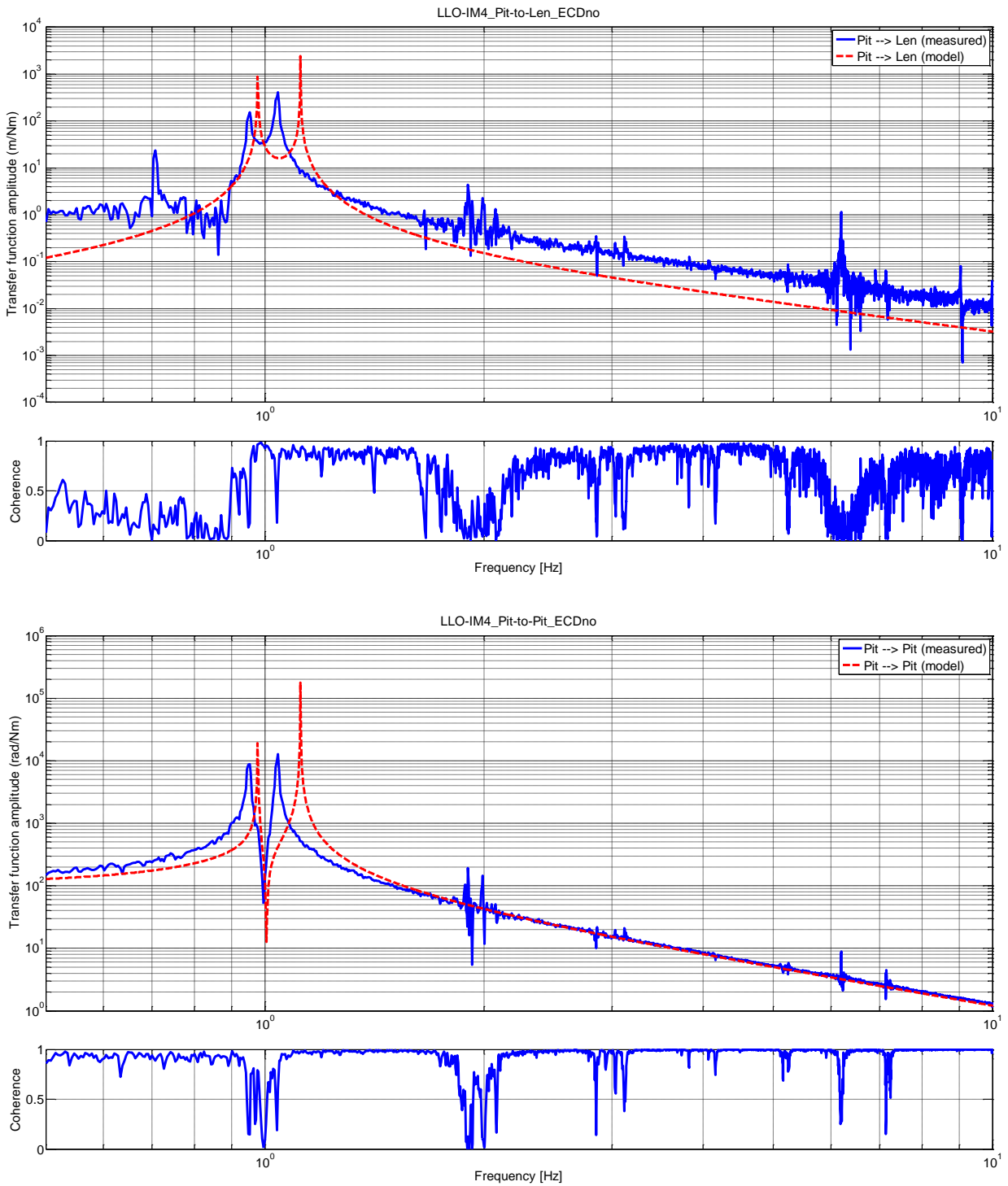
### 3.6.1 Length excitation



No abnormal behavior observed.

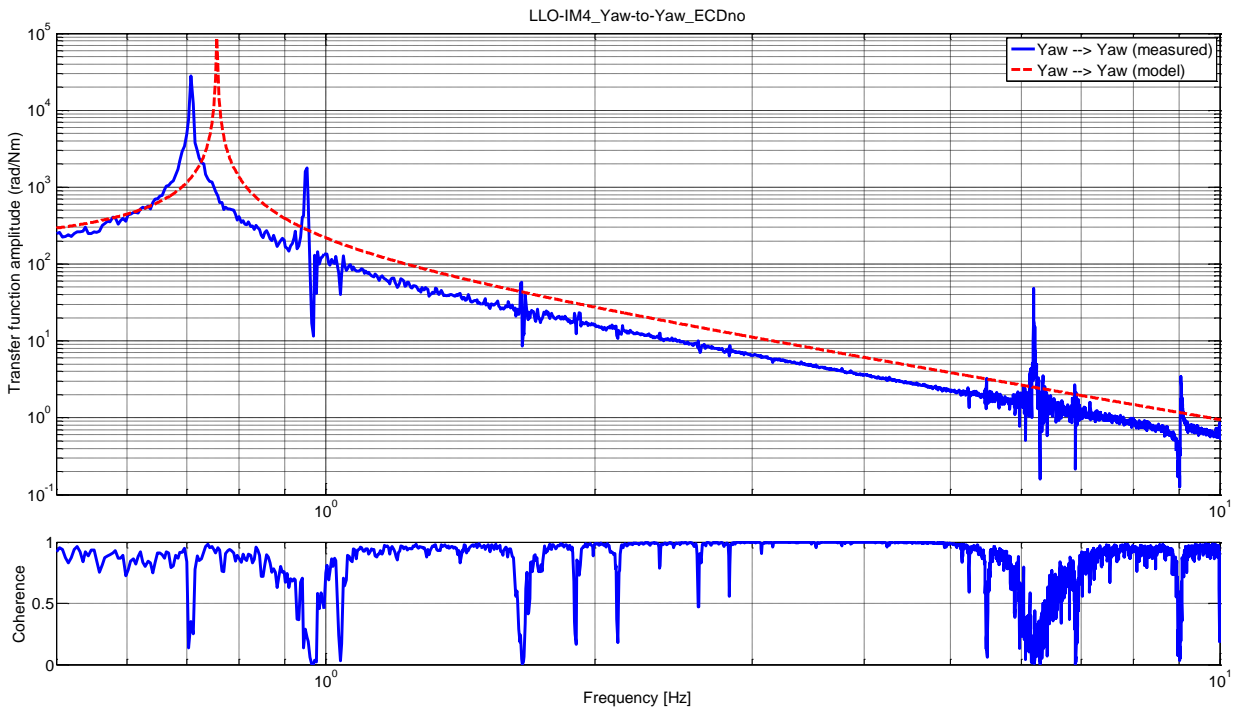
**Passed**

### 3.6.2 Pitch excitation



Possible double peak visible above 1Hz. However, the coherence in that region is low and there is no other indication of anomalies in the remaining TFs. **Passed**

### 3.6.3 Yaw excitation



No abnormal behavior observed.

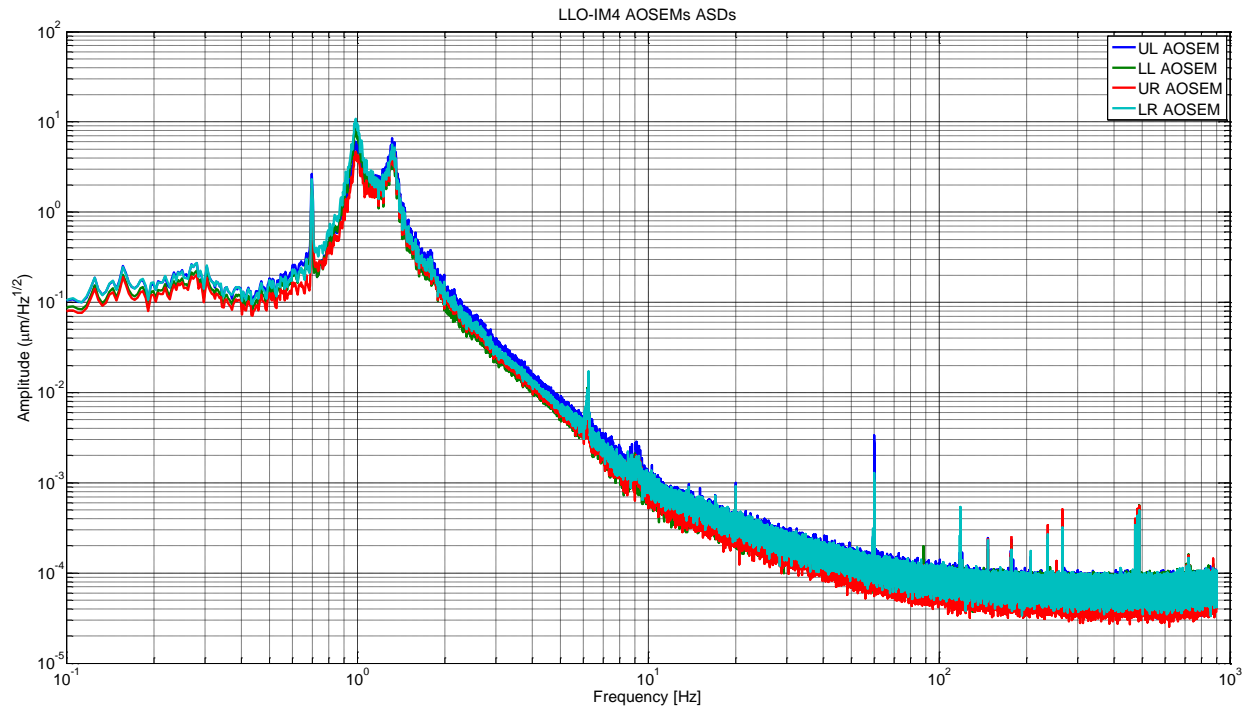
**Passed**

### 3.7 Linear spectra, with ECDs

These measurements have been in vacuum in June 2012.

Data is stored in the SUS SVN repository:

HAUX/L1/Common/dtt\_templates/Review/1024421719\_IM24\_PSD\_5mHz\_noECD\_unDAMPed.txt



There are no requirements associated with this measurement. It is rather intended to be a sanity check looking for strange behaviors and differences between OSEMs. As a reference, high frequency electronic noise is expect to be  $\sim 10^{-4} \mu\text{m}/\text{Hz}^{1/2}$ . **Passed**

### 3.8 Transfer functions, with ECDs

These measurements have been taken on the HAM table, with purge air on, in date 26-Jul-2012. See LLO aLog [4011](#).

Data is stored in the SUS SVN repository:

HAUX/L1/Common/dtt\_templates/1027378807\_IMall\_TF-L\_100000\_10mHz\_ECD\_unDAMPed.xml

HAUX/L1/Common/dtt\_templates/1027383286\_IMall\_TF-Y\_10000\_10mHz\_ECD\_unDAMPed.xml

HAUX/L1/Common/dtt\_templates/1027384091\_IMall\_TF-P\_10000\_10mHz\_ECD\_unDAMPed.xml

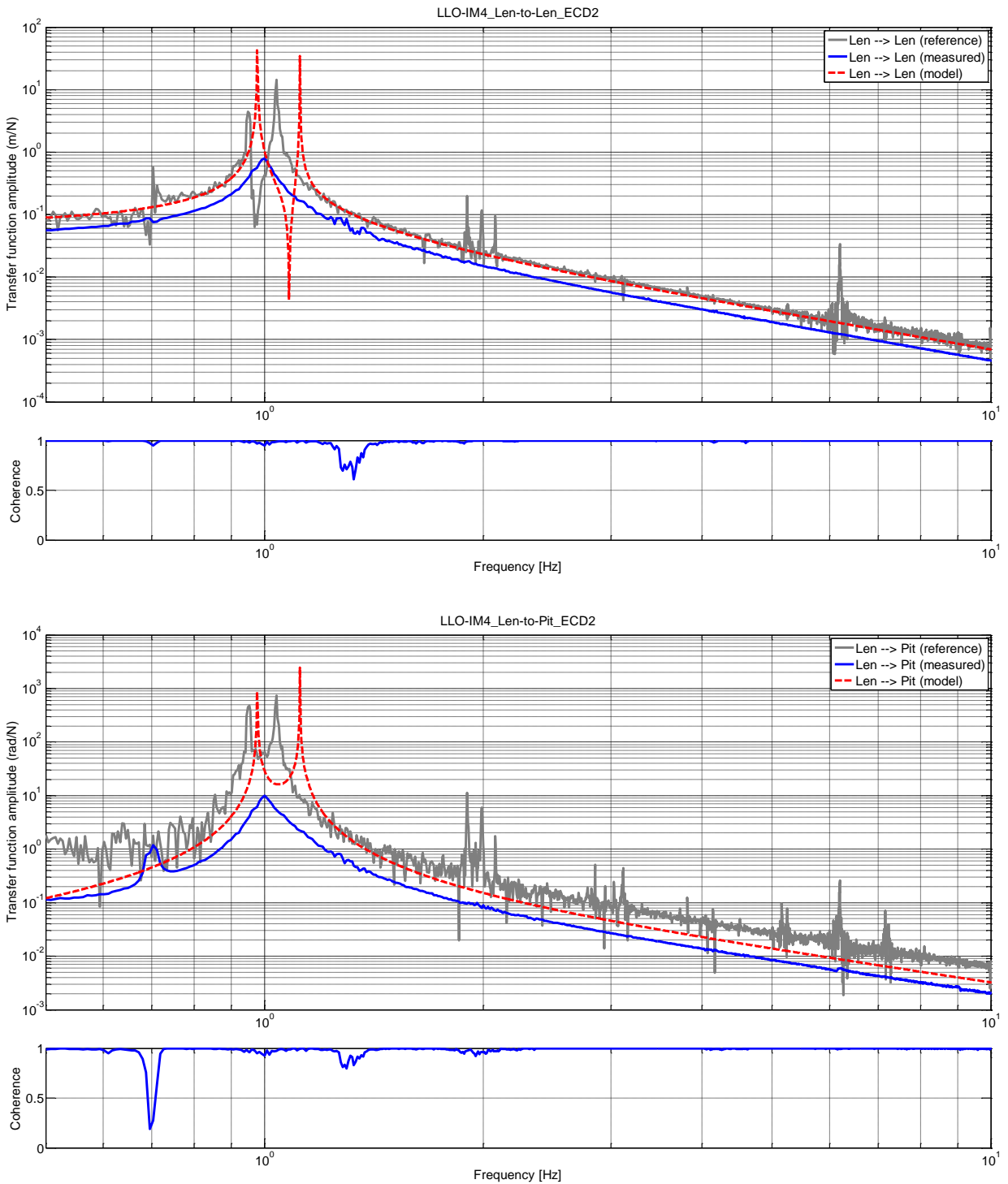
**These measurements need to be repeated in vacuum when the occasion arises.**

Please note:

- Although a preliminary diagonalization of AOSEMs actuation and readout has been performed, it has not been fully optimized and cross-coupling between different DoF can be visible.
- The “reference” curve represents the TF measured with no ECDs; it is the same plotted in section 3.6.
- In principle, we are not interested in any passive damping of yaw, pitch and length, as they can be controlled actively. However, coupling with these DoFs is a known issue of the ECD system designed to damp the other DoFs.

There is no quantitative requirement associated with this measurement, which is mostly intended as a sanity check.

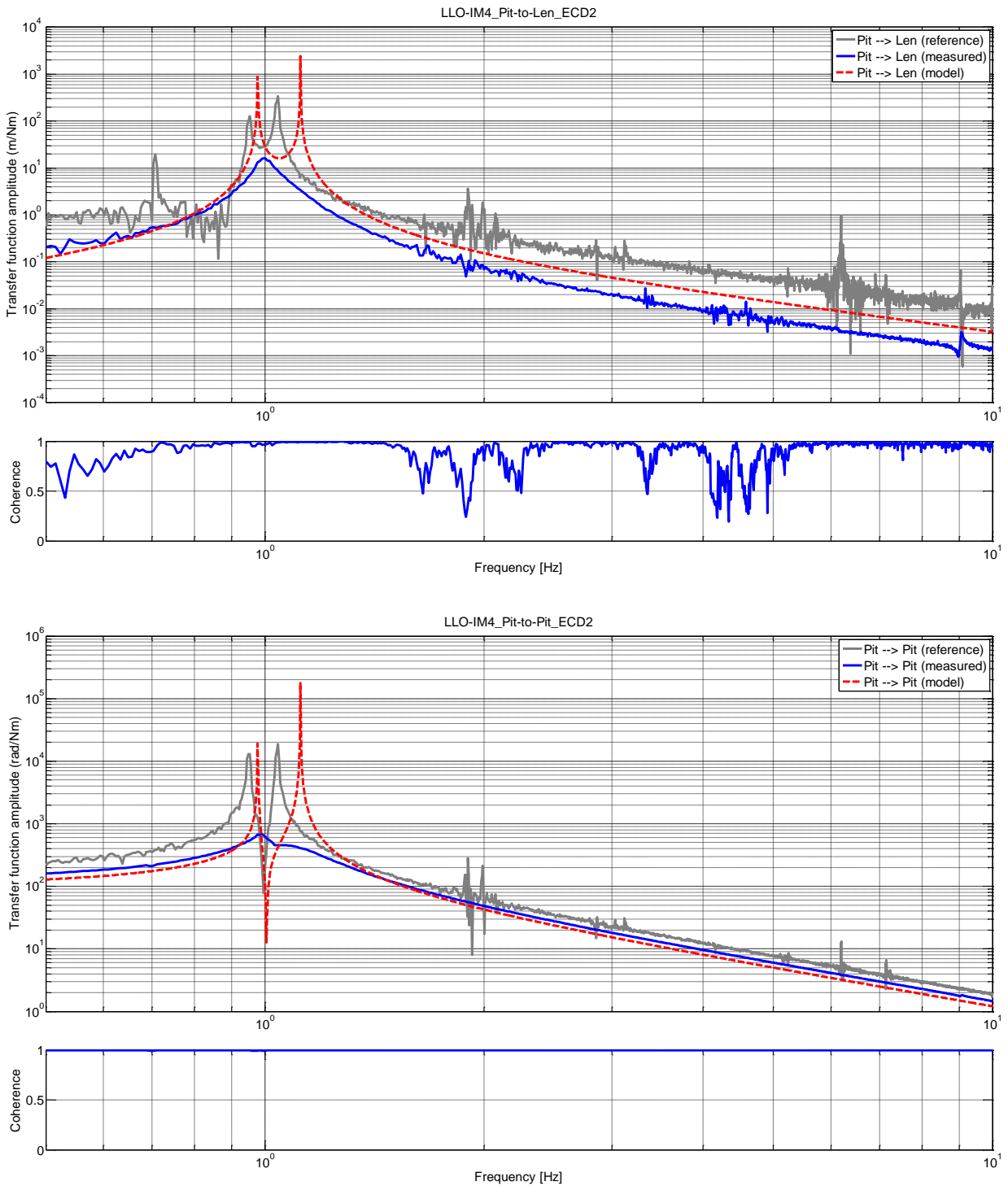
### 3.8.1 Length excitation



No abnormal behavior observed.

Passed

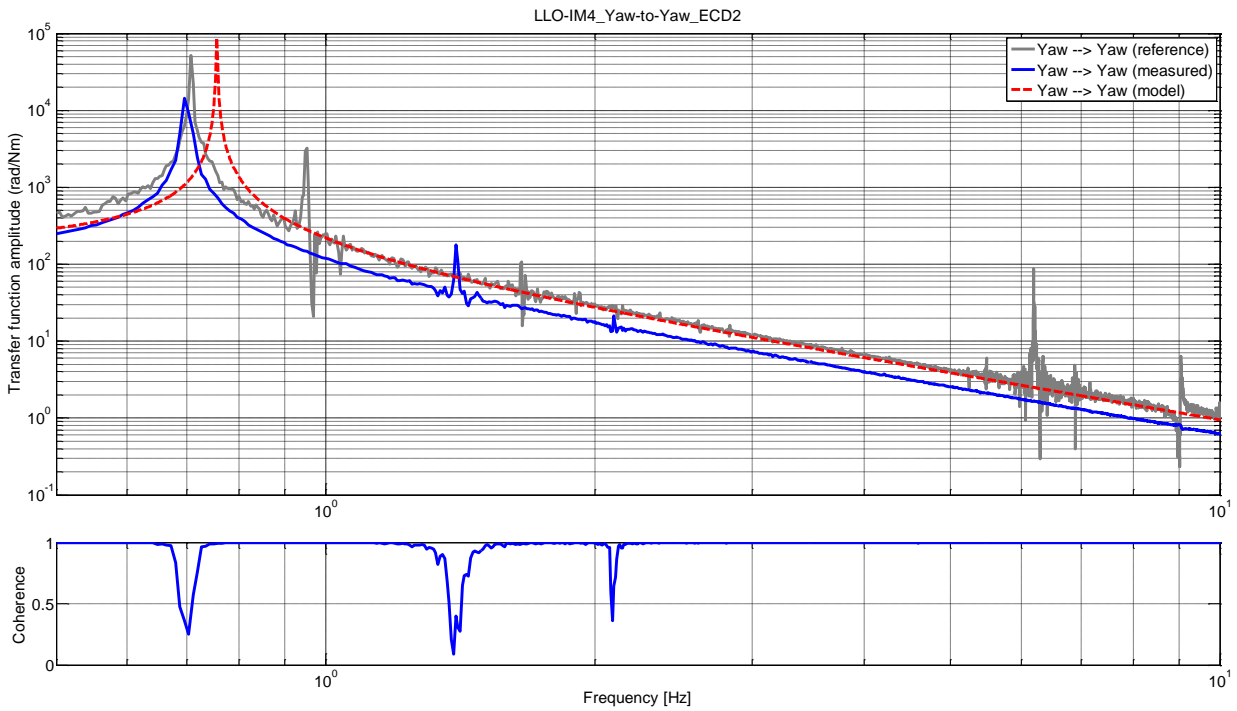
### 3.8.2 Pitch excitation



No abnormal behavior observed.

Passed

### 3.8.3 Yaw excitation



No abnormal behavior observed.

**Passed**

## 3.9 Quality factors with ECDs

Data for these measurements have been taken with different techniques and yielded mixed results. They need to be measured again in a more controlled and uniform way. This can be easily repeated without physically accessing the suspensions, but requires waiting for the right window of opportunity while the IFO is being commissioned.

### 3.9.1 Bounce

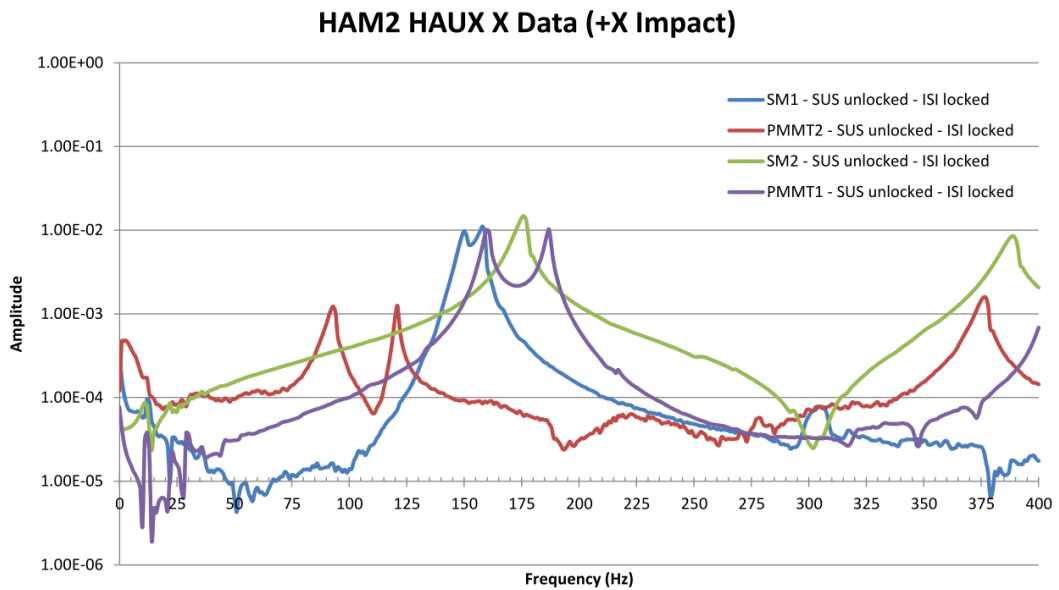
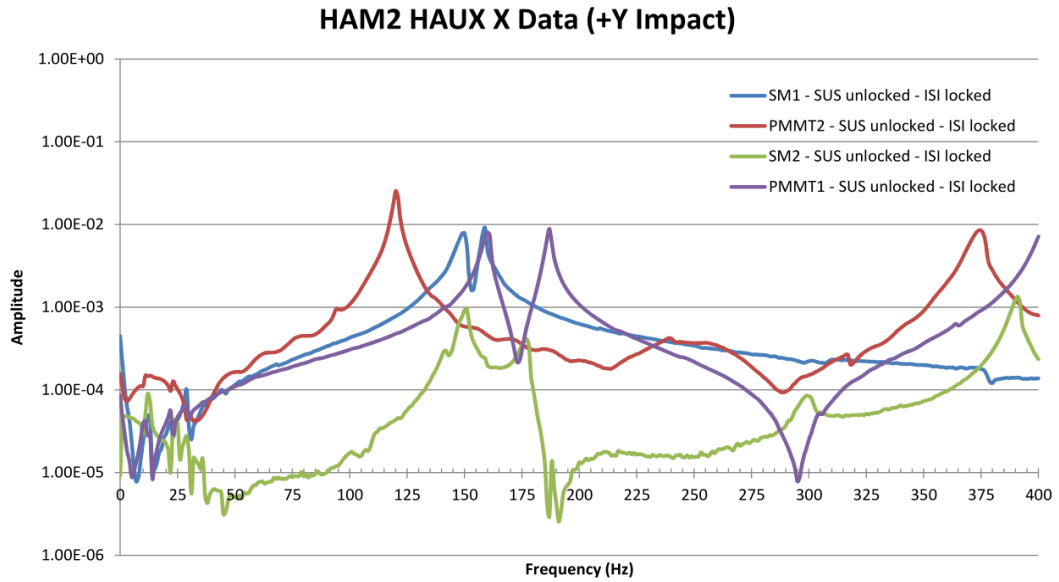
### 3.9.2 Trans

### 3.9.3 Roll



### 3.10 Structural resonances

Measurements have been taken on the HAM table, in final clamping configuration, in date 22-Jul-2012. See LLO aLog [3948](#).



Requirements (from [T1200469](#), § 2.1.4):

- All resonances >150 Hz

**Passed**