Ground Stabilisation with the CERN STACIS 2000 Stable Active Control Isolation System

LAViSta

Laboratories in Annecy working on Vibration Stabilisation

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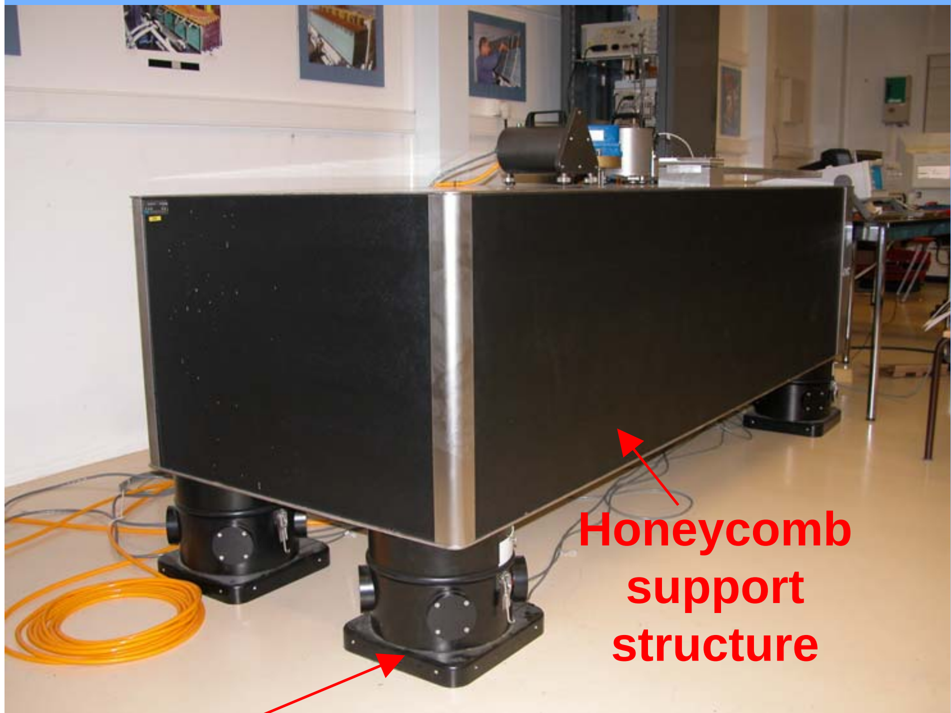
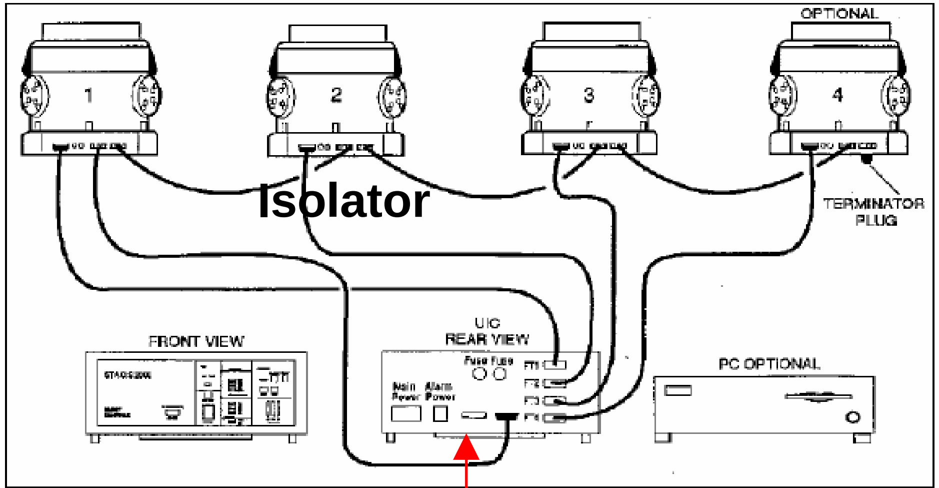
1. Introduction

Presentation of the system



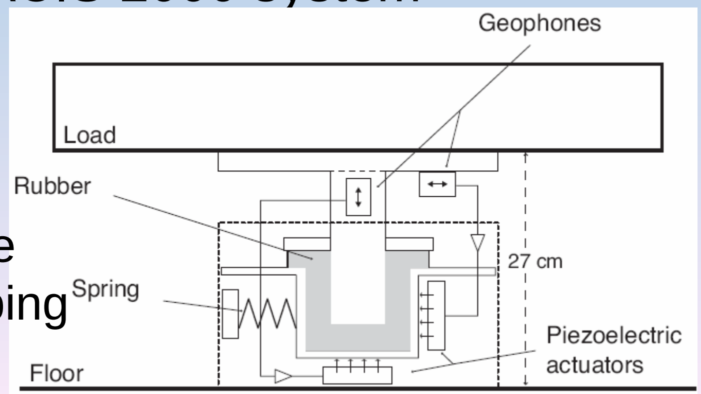


User Interface Controller : to provide communications with and diagnostics of the STACIS 2000 system

Isolator:

- → Stiff rubber: Passive damping
- → One vertical geophone/actuator pair
- → Two horizontal geophone/actuator pairs

} Active damping



1. Introduction

Presentation of the system

Active Degrees of Freedom	6
Active Bandwidth	0.5 to >100Hz
Peak in Transmissibility (active system)	0.4Hz
Resonant Transmissibility	1.1
Isolation Margin	>90% above 2Hz
Settling Time (90% down from peak)	200ms
Static Load Capacity/Isolator	182kg to 500kg
Number of Isolators	3 or 4
Maximum Displacement	15µm peak-peak below 10Hz

✓ **Active degrees of Freedom:** X, Y, Z directions, roll, pitch and yaw

✓ **Advantage/Disadvantage of the use of 3 isolators instead of 4:**

→ Better ground-to-table transverse and longitudinal transmission

→ Slightly worse vertical stability

⇨ Adopt the four feet system because vertical tolerances tighter than the horizontal ones

✓ **Resonant frequency (active system):** 0.4Hz but depends on the load

1. Introduction

Experimental set-up

✓ **Sensors used to measure ground and table vibrations:**

Sensors	Guralp CMG-40T	ENDEVCO86
Sensitivity	1600V/m/s	10V/g
Frequency range	0.033-50Hz	0.01-100Hz
Quantity	2	2

✓ **Limitation of the measurement:**

→ **Guralp sensors:**

- **From 0.033Hz:** Frequency response not flat below
- **To 50Hz:** Frequency response not flat above

→ **ENDEVCO sensors:**

- **From 10Hz:** Electronic noise to high below
- **To 100Hz:** Frequency response not flat above

1. Introduction

Experimental set-up

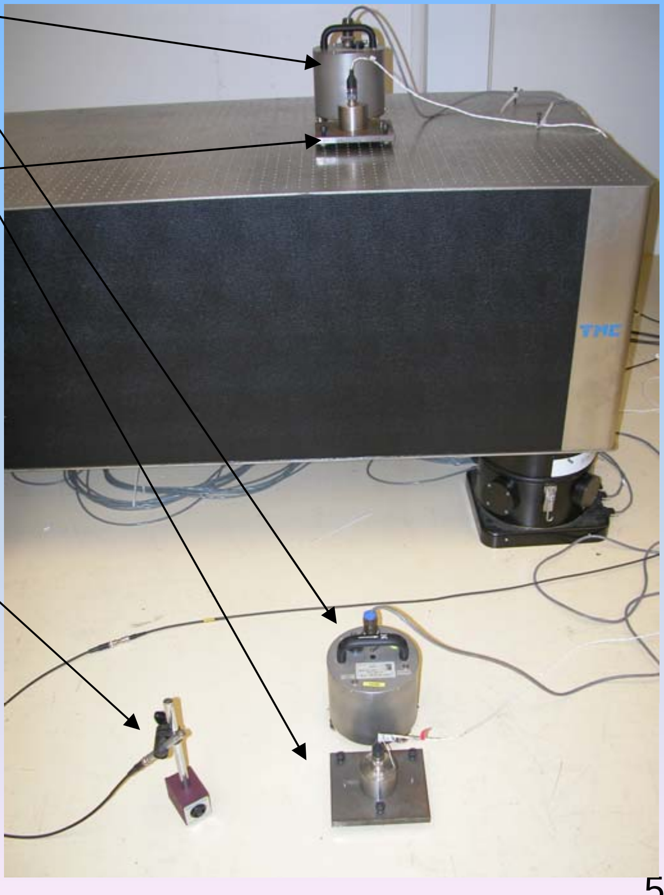
✓ One Guralp velocity sensor on the floor and the other one on the table to measure low frequency vibrations (0.1Hz to 50Hz)

✓ One ENDEVCO accelerometer on the floor and the other one on the table to measure medium frequency vibrations (10Hz to 100Hz)

✓ One microphone on the floor to study acoustic effect on the behaviour of the table

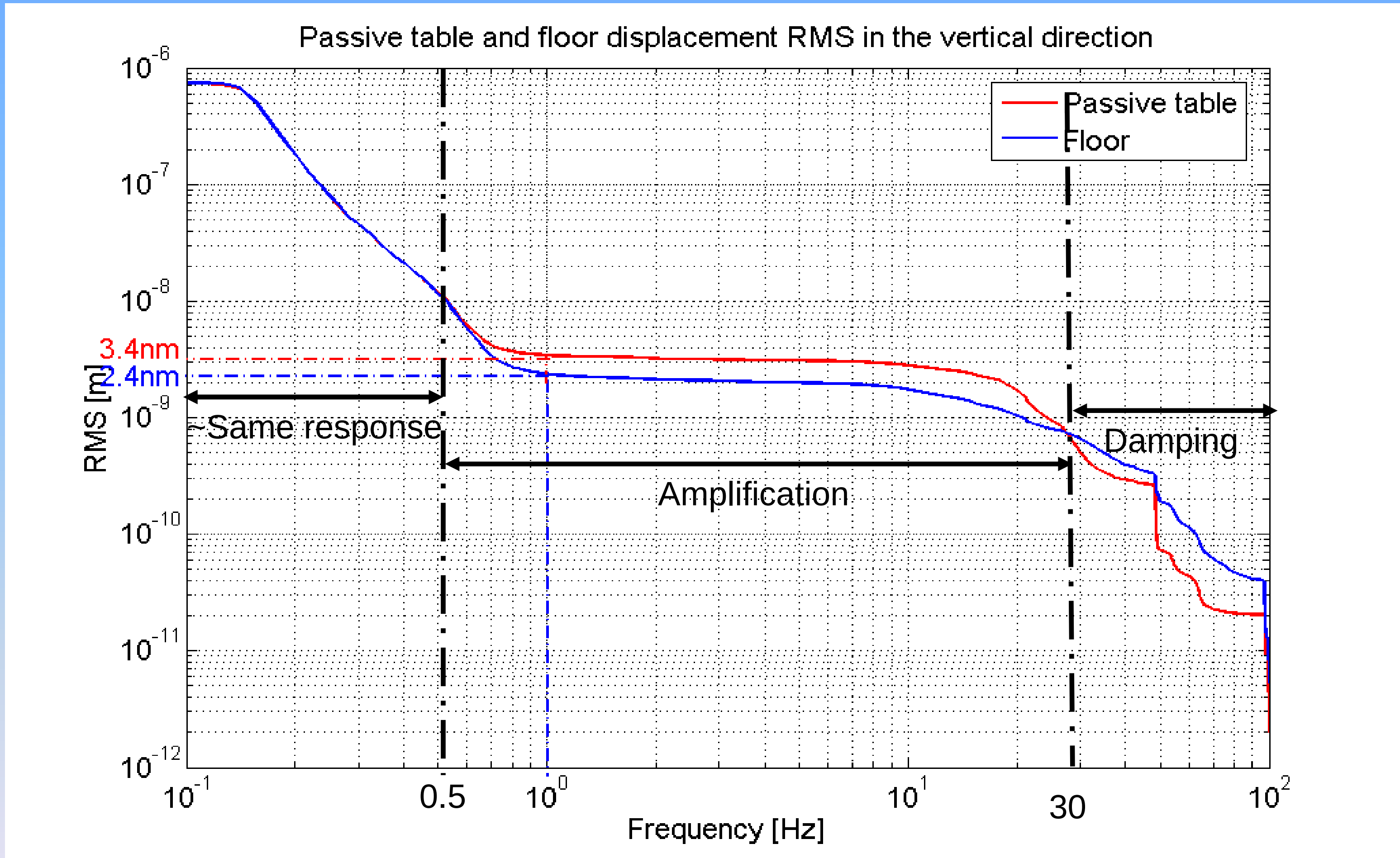
✓ Simultaneous measurements of the 4 sensors

✓ Measurements in the X, Y and Z direction when the table is active and passive



2. Vibrations of the passive table

Vertical direction: Integrated RMS

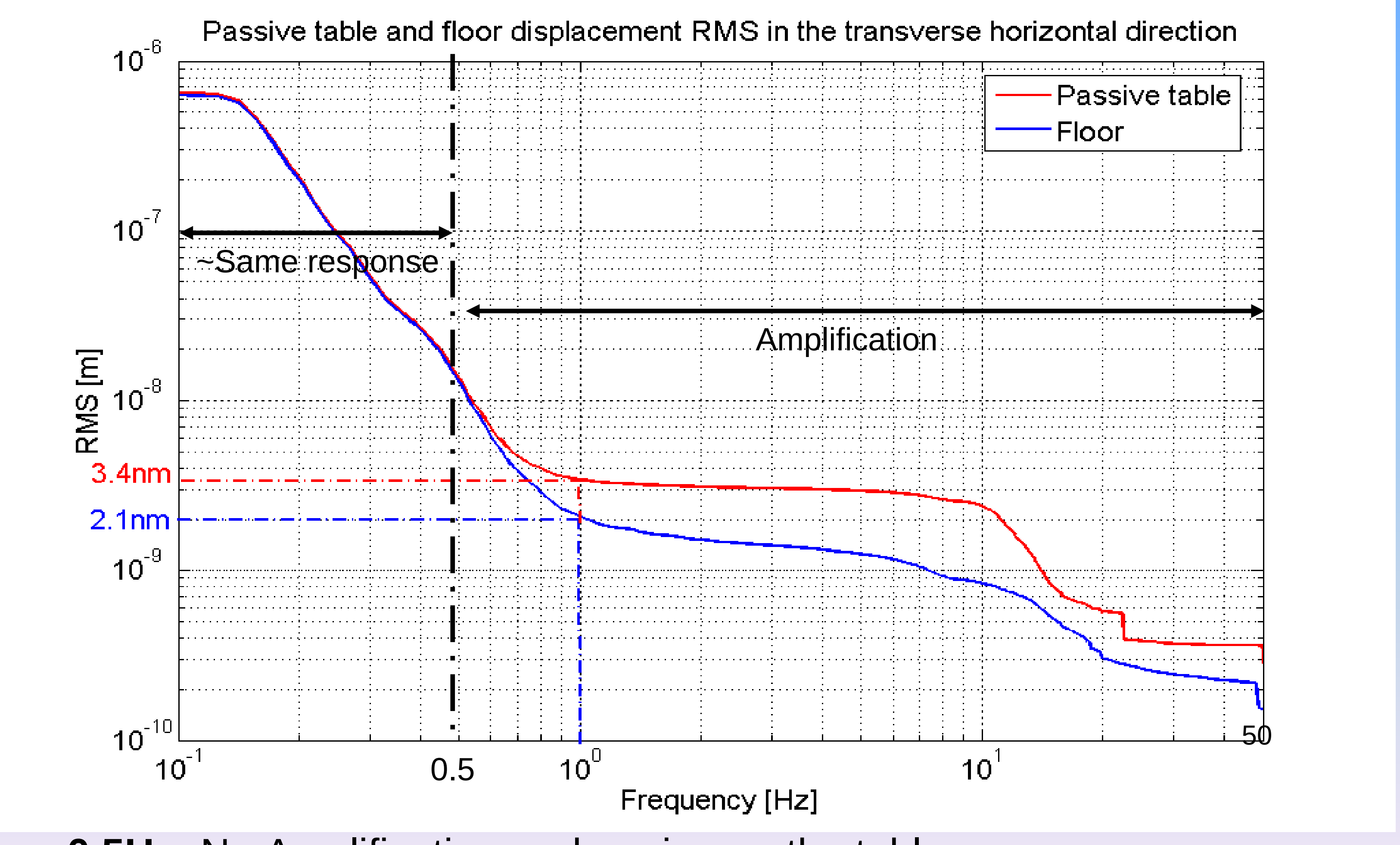


✓ **Below 0.5Hz:** No amplification or damping on the table

✓**Above 0.5Hz:** Amplification and damping begins only above ~30Hz

2. Vibrations of the passive table

Transverse direction: Integrated RMS

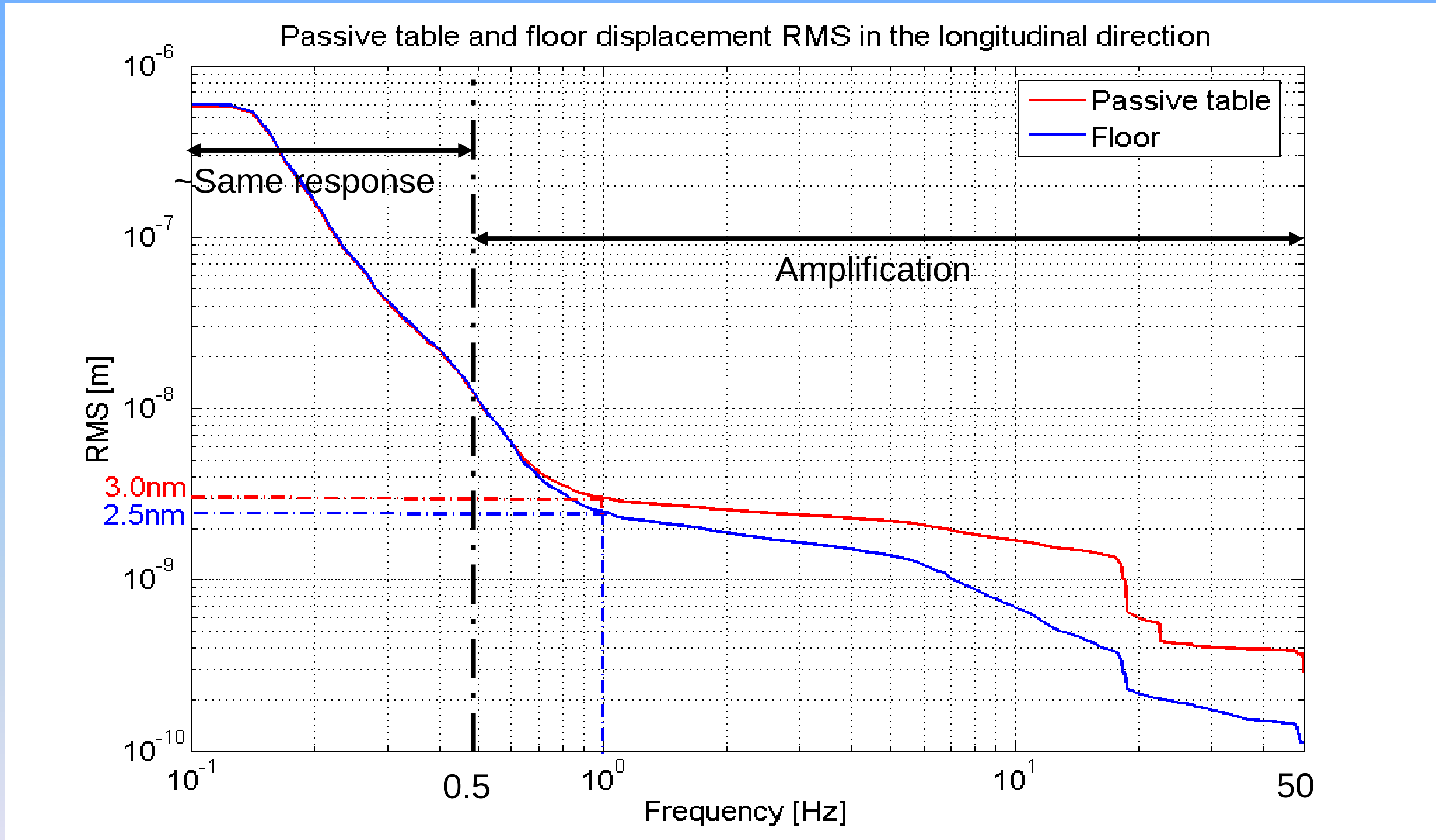


✓ **Below 0.5Hz:** No Amplification or damping on the table

✓ **Above 0.5Hz:** Amplification on the table

2. Vibrations of the passive table

Longitudinal direction: Integrated RMS

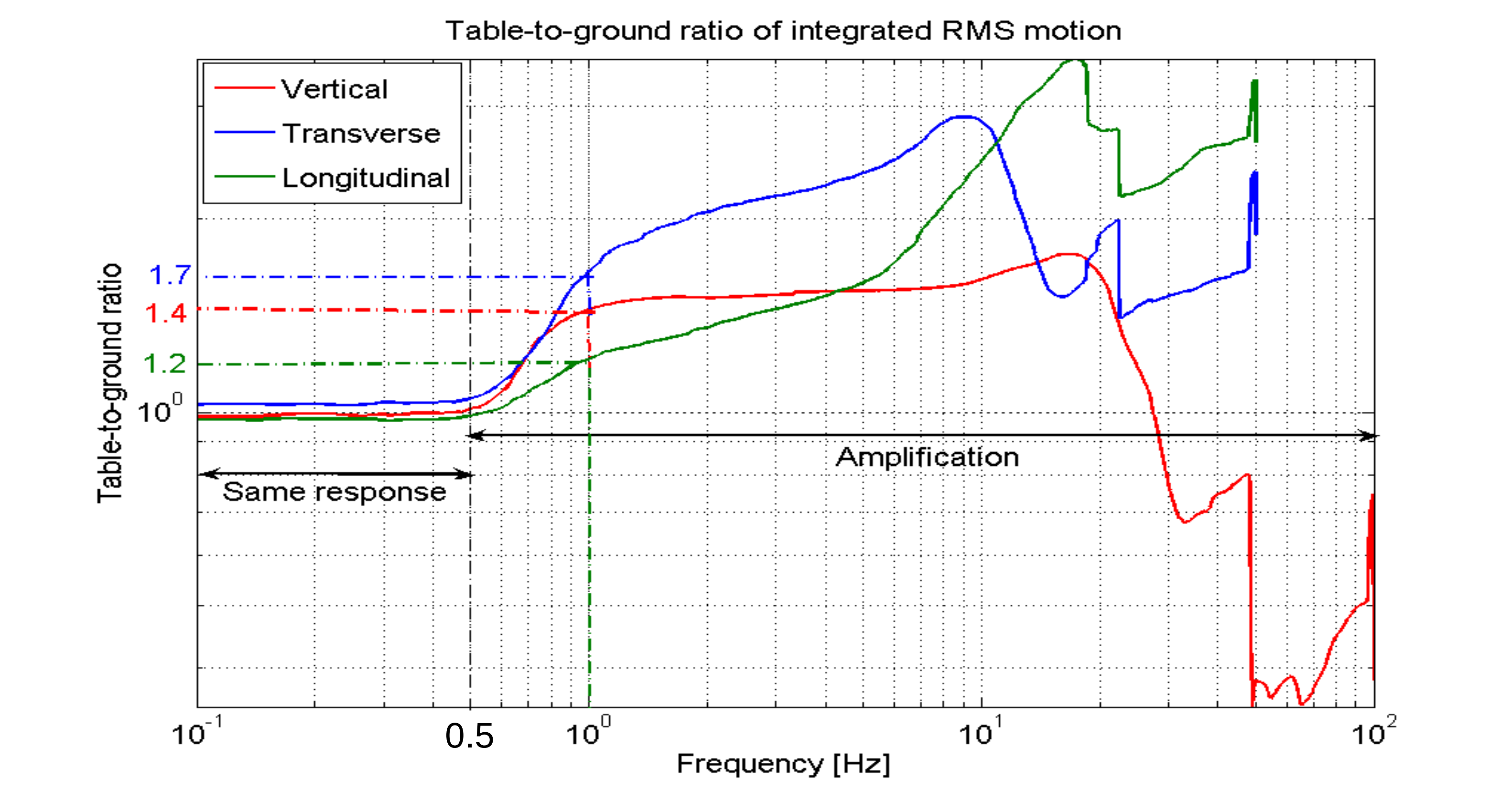


✓ **Below 0.5Hz:** No amplification or damping on the table

✓**Above 0.5Hz:** Amplification on the table

2. Vibrations of the passive table

Transfer function of the table integrated RMS

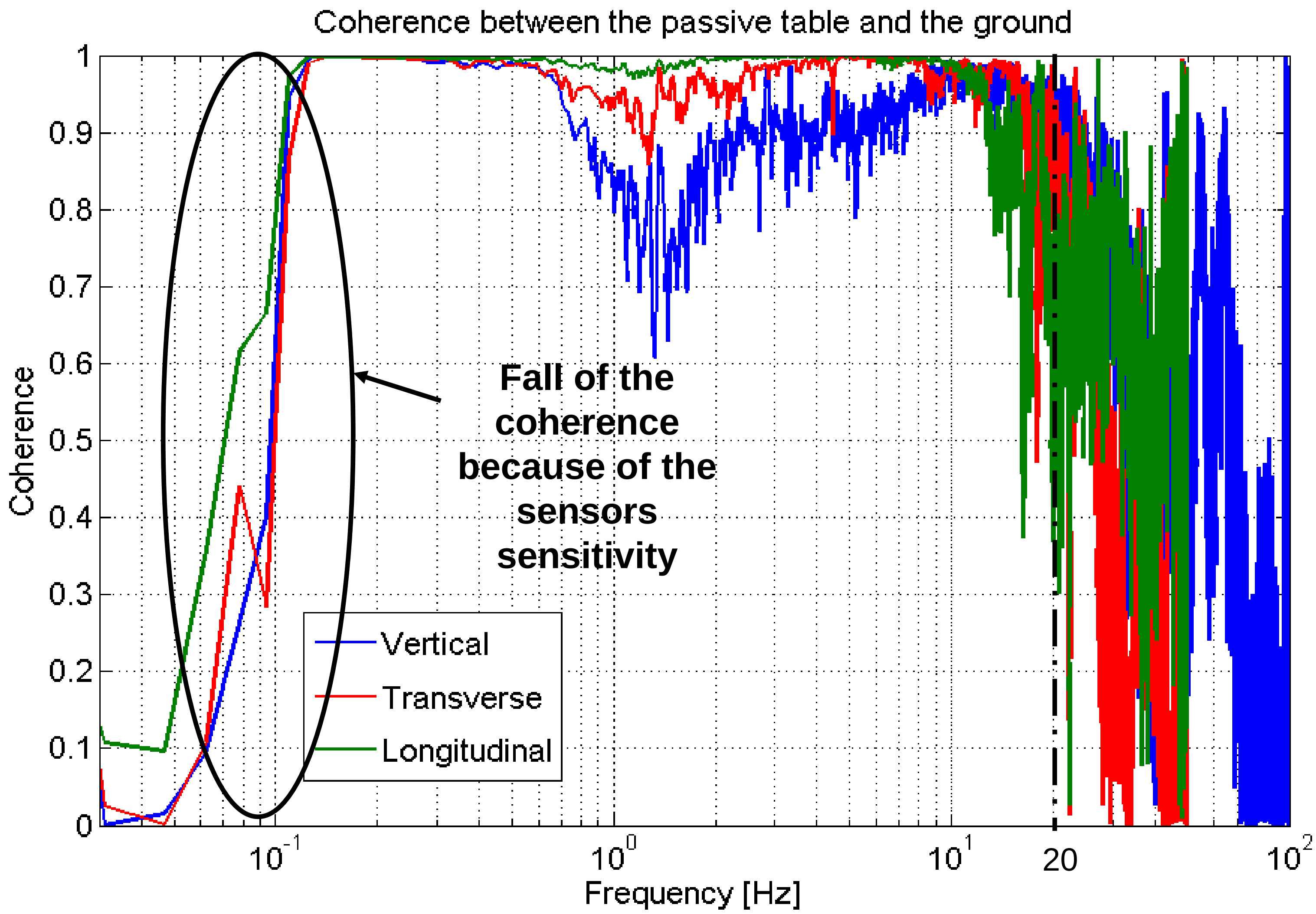


✓ **From 0.1Hz to ~0.5Hz: No damping or amplification** on the table in the 3 directions

✓ **Above ~0.5Hz: Amplification on the table in the 3 directions**

→ Vertical direction: factor 1.5 of amplification above 1Hz

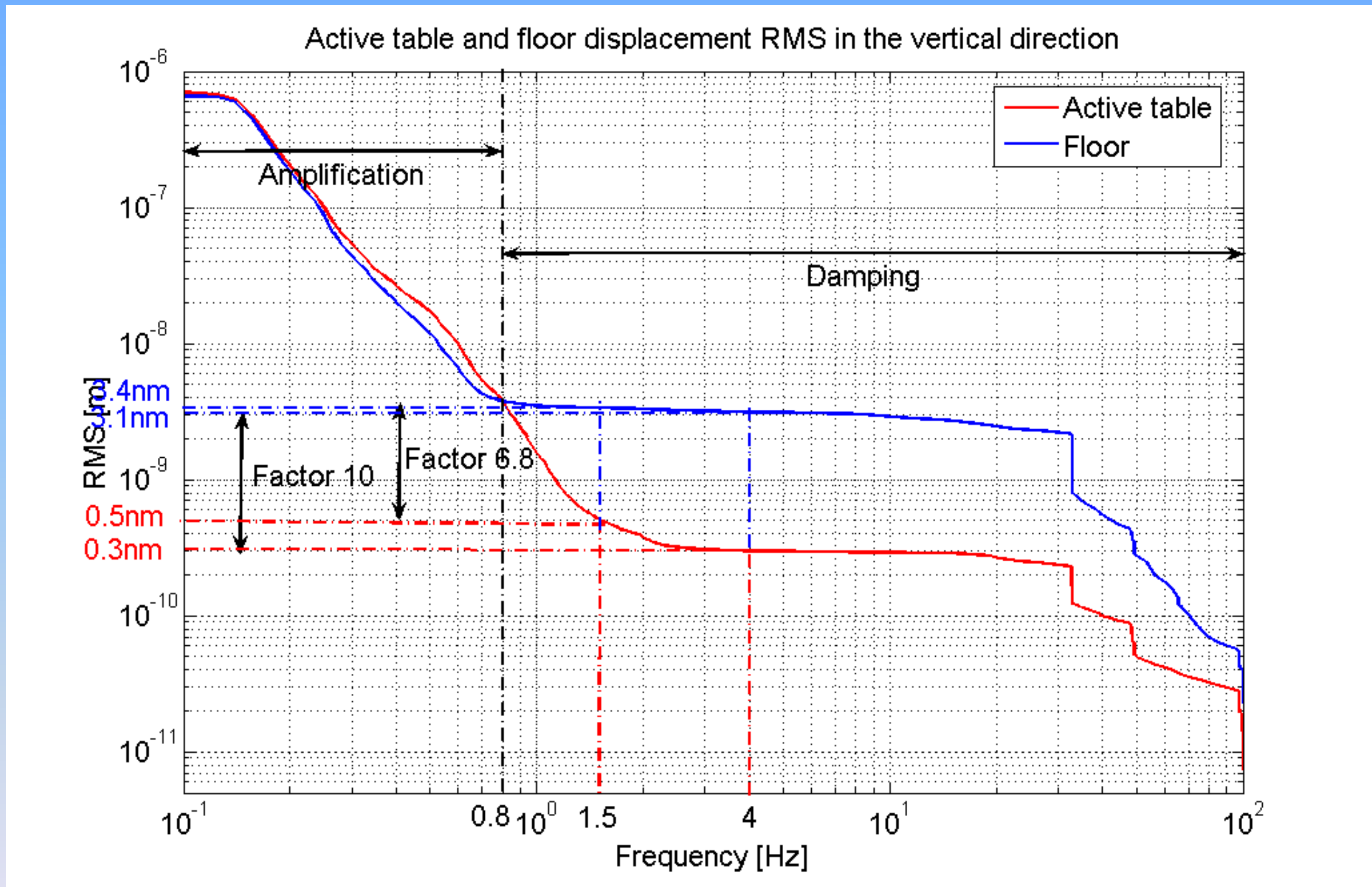
2. Vibrations of the passive table



✓ **Coherence between passive table and ground:** fall above 20Hz

3. Vibrations of the active table

Vertical direction: integrated RMS



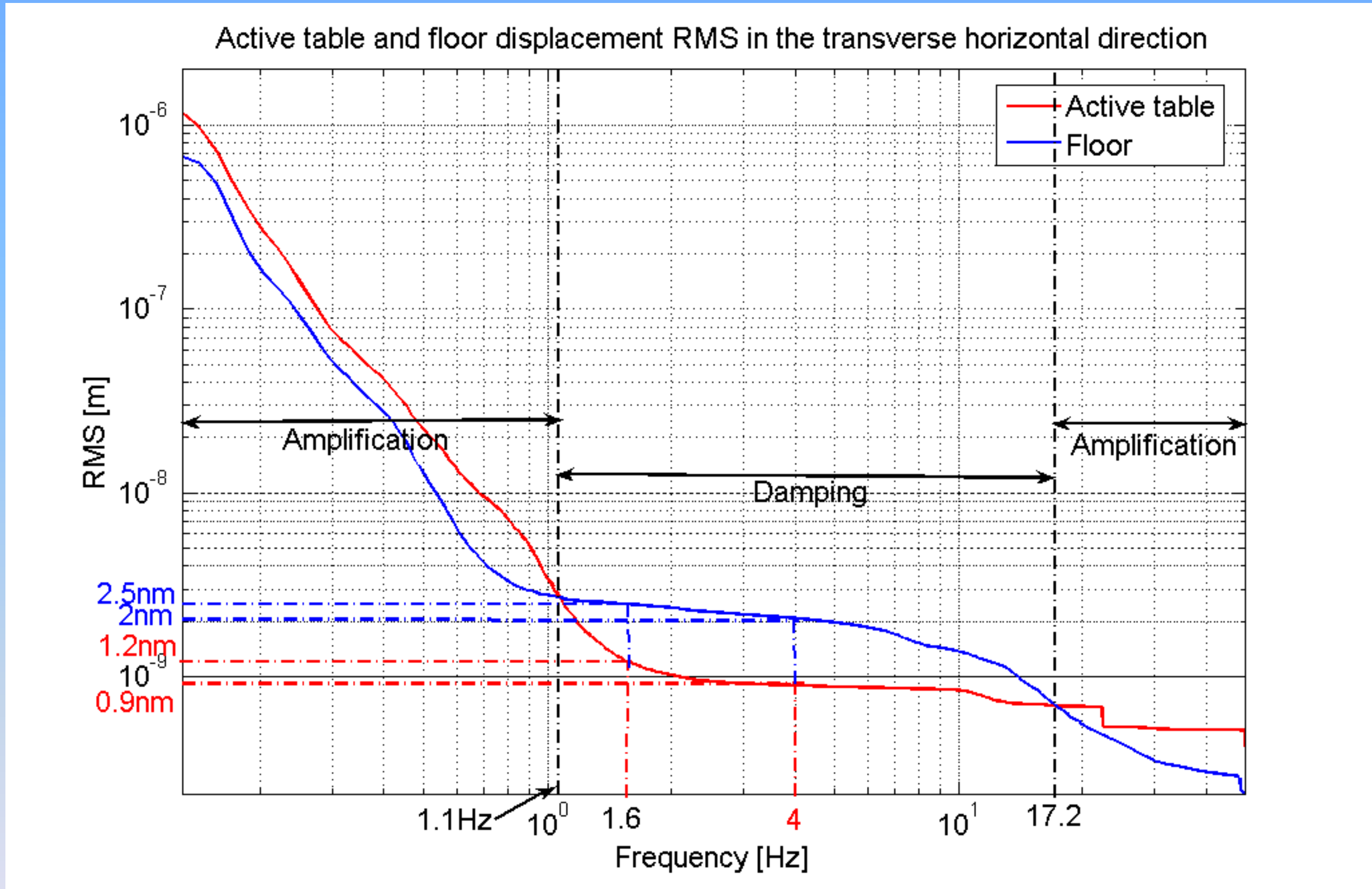
✓ **Below 0.8Hz:** Amplification on the table

✓ **Above 0.8Hz:** Damping on the table

→ Factor 7 of damping above 1.5Hz

3. Vibrations of the active table

Transverse direction: Integrated RMS



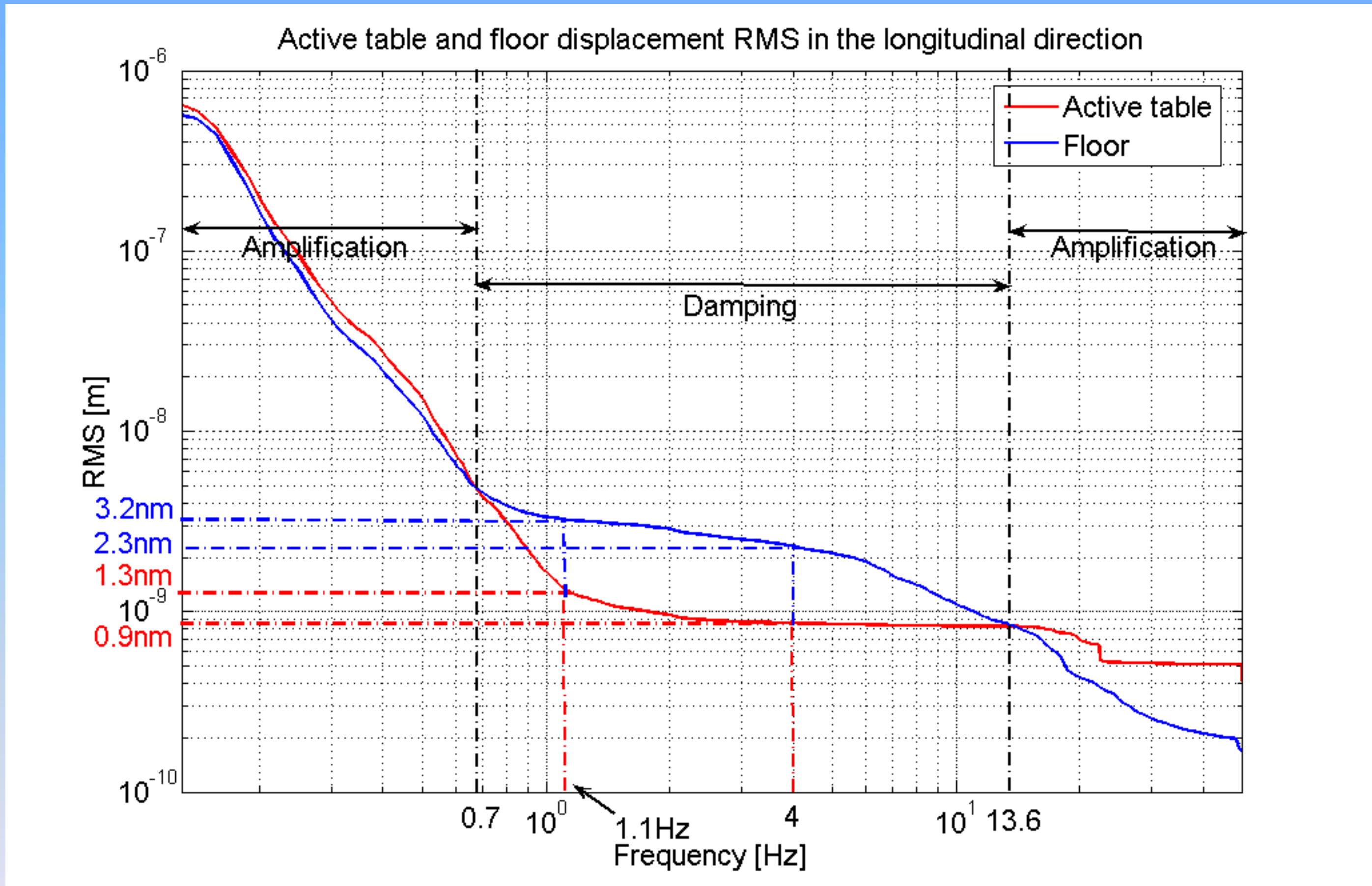
✓ **Below 1.1Hz:** Amplification on the table

✓ **Above 1.1Hz:** Damping on the table

→ Factor 2 of damping above 1.6Hz

3. Vibrations of the active table

Longitudinal direction: Integrated RMS

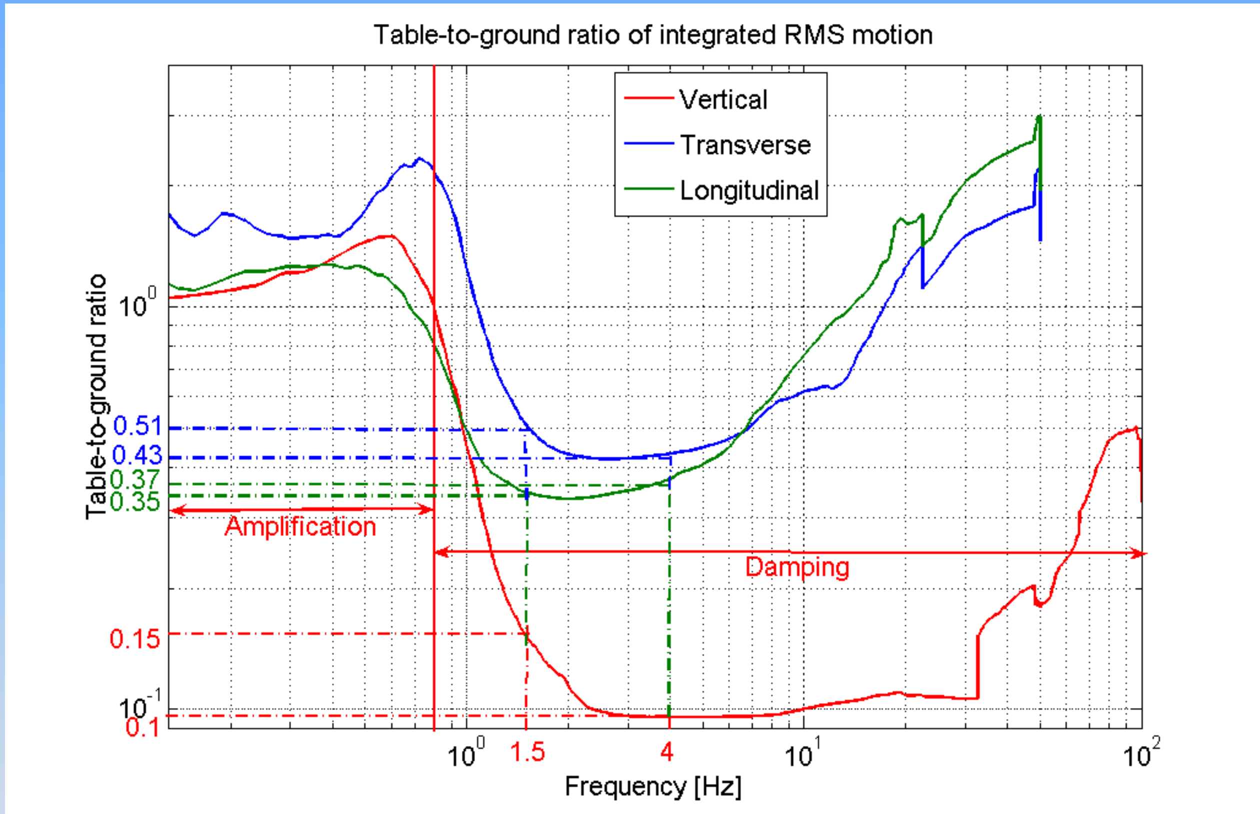


✓ **Below 0.7Hz:** Amplification on the table ✓ **Above 0.7Hz:** Damping on the table

→ Factor 2.5 of damping above 1.1Hz

3. Vibrations of the active table

Summary: Transfer function of the table integrated RMS



✓ **From 0.1Hz to ~0.8Hz: Amplification** on the table in the 3 directions

→ Vertical direction: up to a factor 1.5 of amplification (at 0.6Hz)

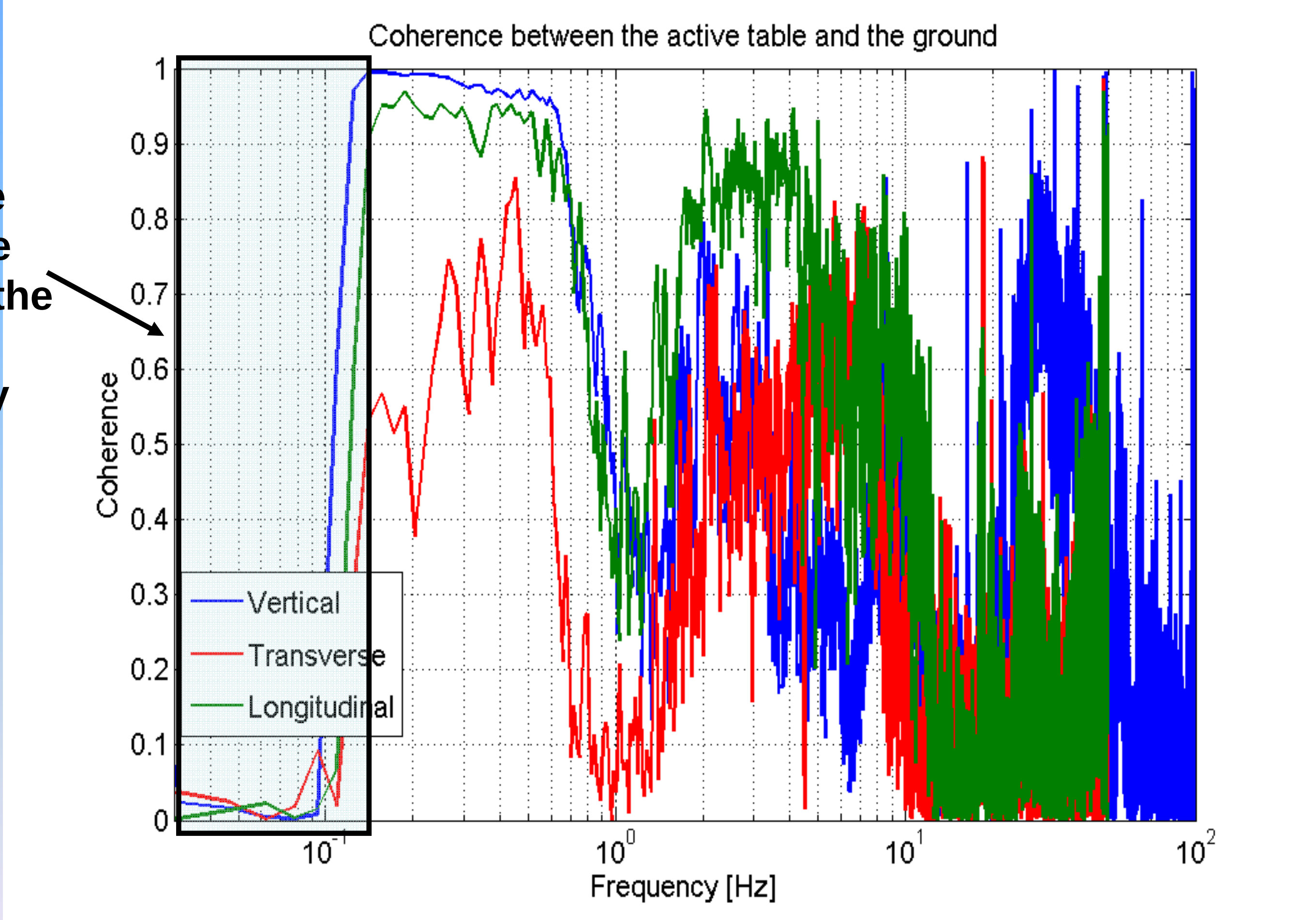
✓ **Above ~0.8Hz: Damping on the table in the 3 directions**

→ Vertical direction: factor 0.15 of damping at 1.5Hz

3. Vibrations of the active table

Coherence

Fall of the coherence because of the sensors sensitivity



✓ Below 0.8Hz: Good coherence between the ground and the active table

✓ Above 0.8Hz: fall of this coherence

4. Discussion of the use of the table for ATF2

✓ **Vibration tolerances at ATF2**

→ Tightest in the vertical direction: FD ~ 5nm

✓ **Today at ATF2**

→ Active beam-based feedback < 0.1Hz

→ Vertical Integrated RMS vibration above:

- 0.1Hz ~300 nm
- 1Hz ~80 nm

⇒ Would need at least ~0.01 damping factor between 0.1 and 1 Hz in the event of 100% incoherent between FD and IP

4. Discussion of the use of the table for ATF2

✓ Low frequency vibrations: 0.1Hz - 1Hz

→ Expected vibrations in the vertical direction: 300nm → 80nm

Table (Vertical direction)	Passive	Active
Amplification	1	1.5
Coherence Table/Floor	0.9	0.9

⇨ Passive table better because of the amplification in the active mode

✓ Medium frequency vibrations: 1Hz - 20Hz

→ Expected vibrations in the vertical direction: 80nm → 2nm

Table (Vertical direction)	Passive	Active
Amplification	1.5	0.1
Coherence Table/Floor	0.9	0.3

- Loss of coherence in the active mode

  → Even if FD motion very small, relative motion between FD and Shintake big

⇨ Passive table better

4. Slow drifts of the table

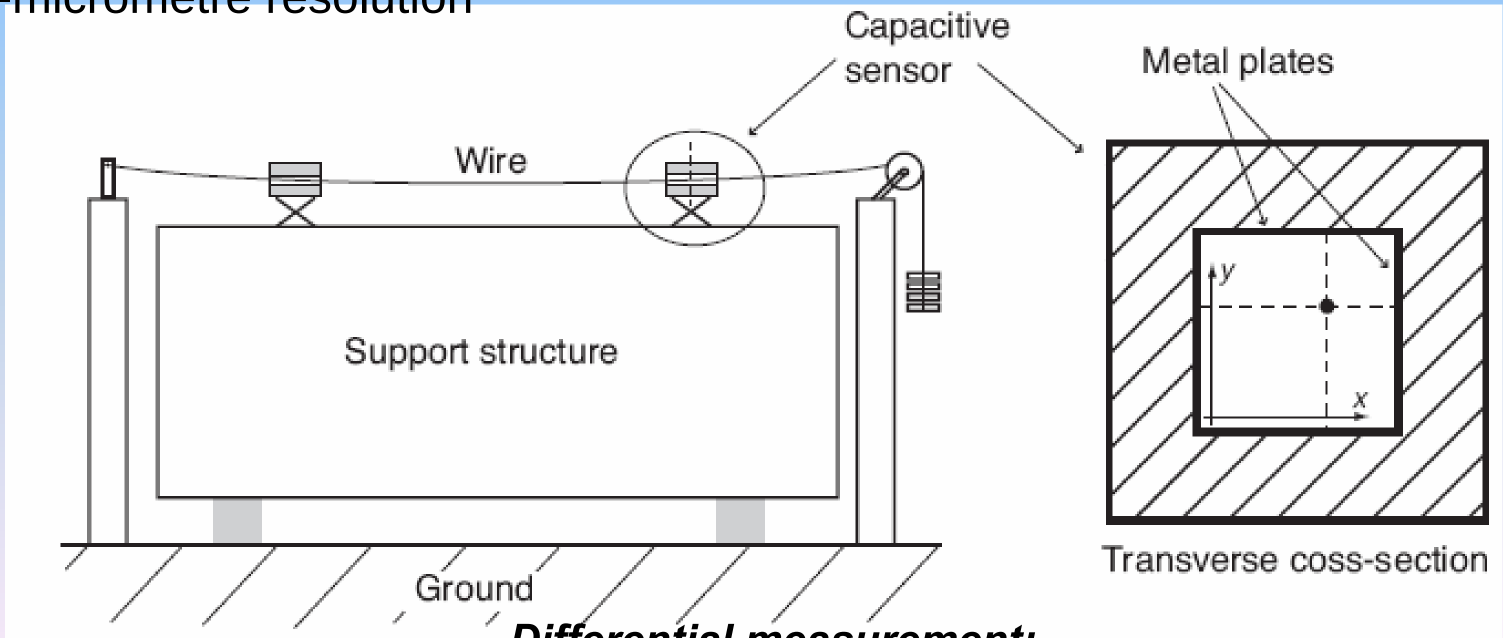
Work done by Stefano Redaelli at CERN

Description of the Stretched wire system

Stretched wire system: Measurement of low drifts of the table position with respect to ground in horizontal and vertical directions

✓ As reference a metal wire is stretched all along the honeycomb support structure and is fixed to the ground

✓ Capacitive, noncontact sensors are used to measure the wire position with a sub-micrometre resolution



Differential measurement:
Four inner metal surfaces provide two position measurement per measuring plane

4. Slow drifts of the table

Work done by Stefano Redaelli at CERN

Description of the Stretched wire system

Table 4.8: Technical specifications of the WPS2-D stretched-wire system by *Fogale Nanotech*.

Parameter	Specification
Number of pick-up sensors	3
Measurement range (both planes)	± 5 mm
Output voltage	0 V-10 V
Average sensitivity (both planes)	1 V/mm
Linearity (full range)	± 0.150 mm
Linearity (± 0.5 mm)	$\approx \pm 1.5 \times 10^{-3}$ mm
Horizontal to vertical coupling (full range)	0.8 mm
Uncertainty of reference centre	± 0.1 mm
Thermal drift	0.5 μm/°C
Bandwidth (1st order)	10 Hz
Measurement noise (full bandwidth, 3 m wire)	0.3 μm

- ✓ Resolution over the full bandwidth: 0.3um
- ✓ Slow acquisition of 1Hz: nominal resolution in the tens of nanometre range

4. Slow drifts of the table

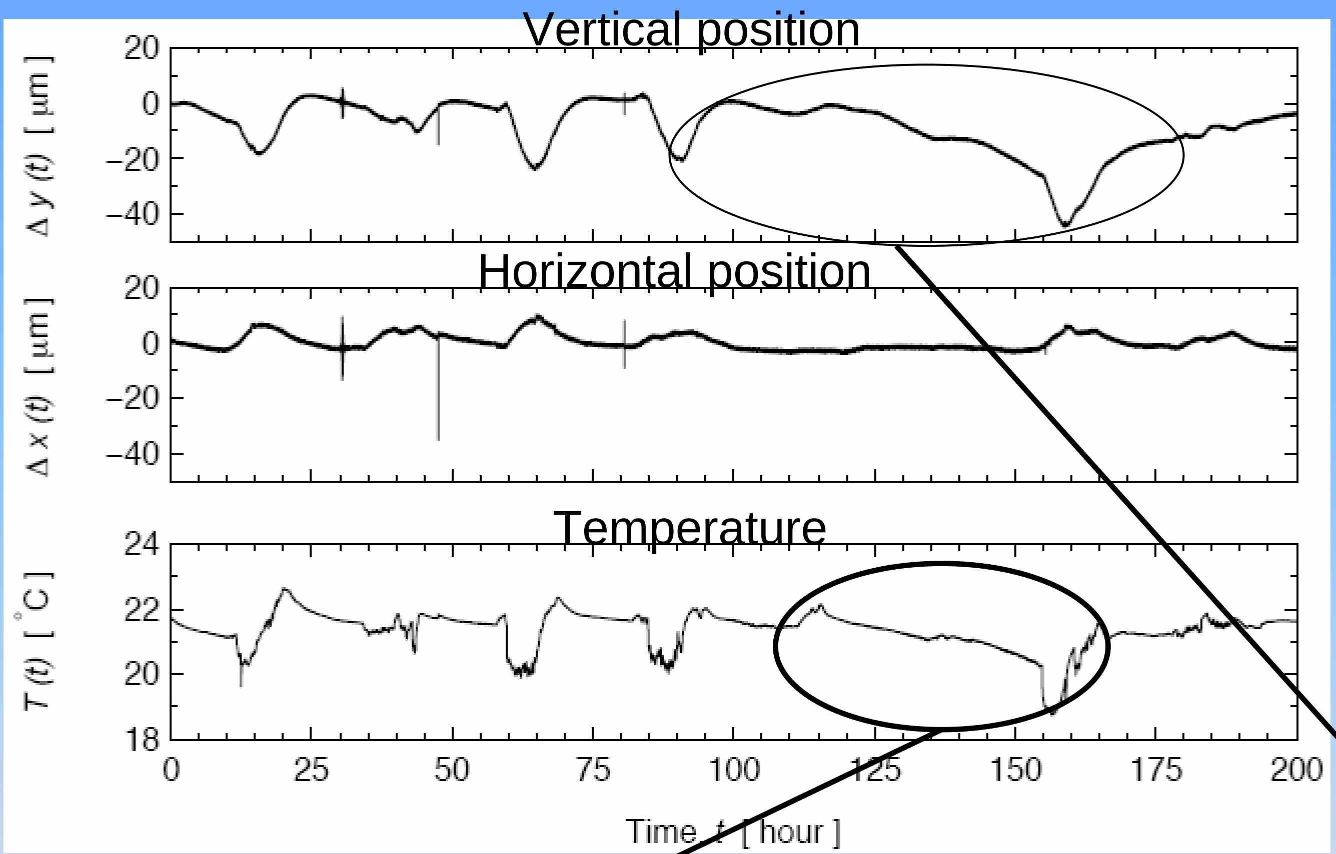
Work done by Stefano Redaelli at CERN

Measurements performed

- ✓ Measurement of vertical and horizontal table positions versus time
- ✓ Total measurement time: approximately eight days
- ✓ Acquisition frequency: 1Hz
  - → Stretched wire system resolution: approximately 30nm
- ✓ Ambient temperature versus time measured in the vicinities of the table

4. Slow drifts of the table

Work done by Stefano Redaelli at CERN



✓ **Vertical position:** Measurement of a maximum variation of approximately 40 μm for a temperature variation of ≈ 3 ◦C

✓ **Horizontal position:** Variations three to four times smaller

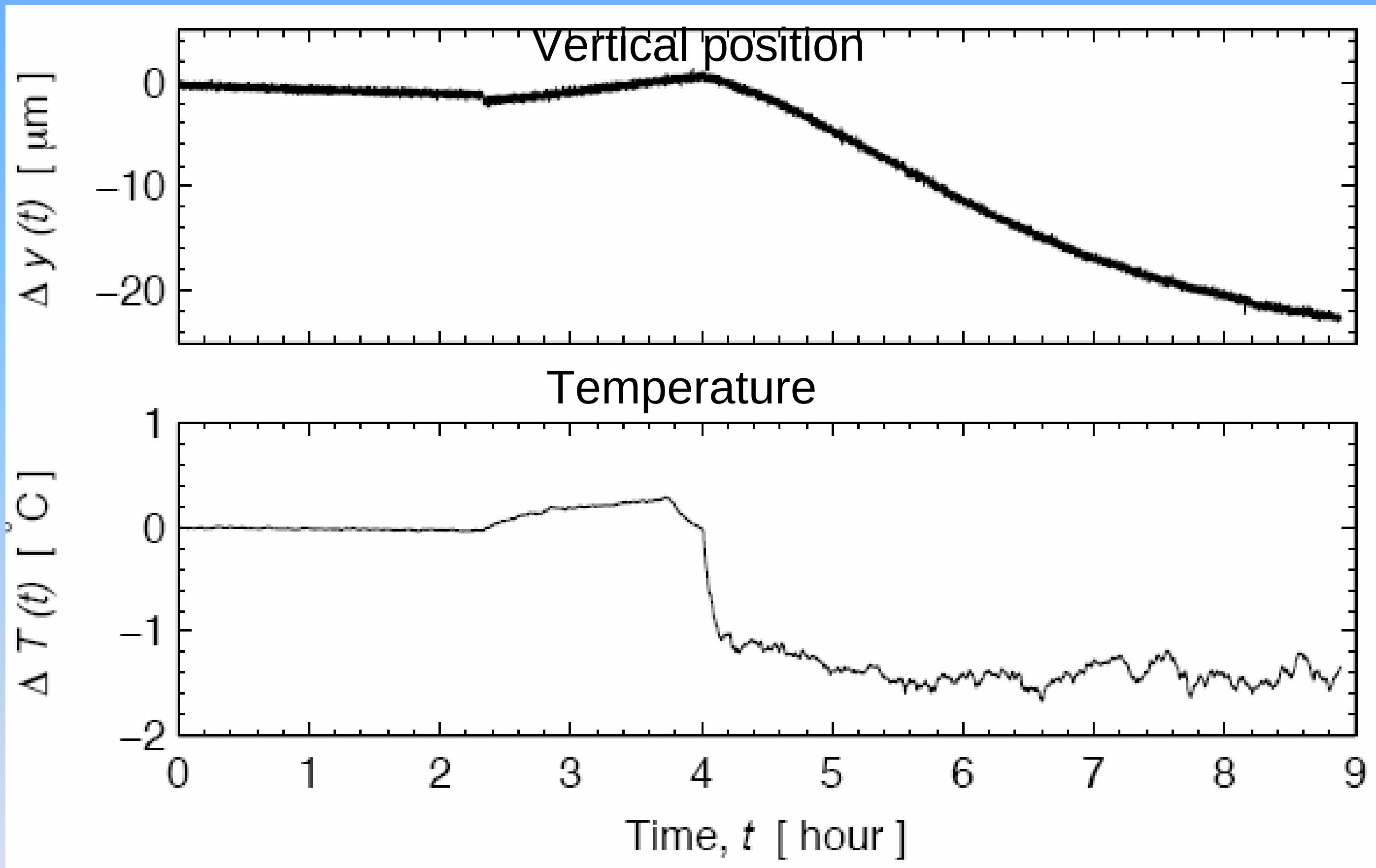
✓ **Explanation:** Decrease of temperature → Lowering of table height

⇨ Probably due to the shrinking of the rubber in each isolator

4. Slow drifts of the table

Work done by Stefano Redaelli at CERN

✓ **Details of temperature variations on the vertical table alignment:**



✓ **Sudden temperature variation of approximately 1.5 ◦C**

→ Slow drift of the table vertical position, with a maximum of ≈ 20 *μ*m after 5 hours

→ Variation of 1 nm per second

Conclusion

- ✓ At low and medium frequency: passive mode better than active because:
  - Low frequency: amplification reaches factor 1.5
  - Medium frequency: breakdown of coherence

- ✓ Better to find a passive system with no eigenfrequencies up to 50Hz
  → Will investigate for example a stiff table

- ✓ CLIC table adapted for frequencies from 1Hz to 100Hz

- ✓ **Slow drift of the table for a temperature variation of 3°C:**
  → Z direction: 40um table-to-ground motion
  → X, Y direction: 3 or 4 times smaller

Program at LAPP

- 4 Movers being shipped from SLAC to Annecy
=>vibration measurements with equivalent masses (like 4 magnets)
- Possibility of shipping modified FFTB magnets first to Annecy then to KEK for realistic vibration measurements and comparison to simulation
- Evaluating the usefulness of the CLIC table for ATF2 :
Low frequency measurements (maybe comparative capacitive sensors) but difficult to support
- Vibration measurements at KEK with Annecy material
- Modify movers that are 8cm too high