Vibroacoustic study of an audiophile equipment rack

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Revision: 1.0 (16 January 2026)
Unofficial translation from the original French document

1 Introduction

This memo documents the series of tests conducted at the request and on behalf of The Symbiose, regarding the quality of an audiophile rack.

The rack's function is in principle limited to its role as a support. "Audiophile quality" therefore amounts to obtaining a rack that is as inert as possible, more specifically:

- that it does not amplify, or only slightly, vibrations transmitted by the floor (so-called structure-borne path)
- that it does not respond, or only slightly, to acoustic pressure fluctuations (so-called air-borne path)

In both cases, the associated physical quantity is the vibrational acceleration transmitted to the amplification electronics. There is no absolute criterion provided by manufacturers below which a rack can be considered fully satisfactory. We therefore adopted a relative approach, comparing the vibration levels measured on the underside of the surface supporting the amplification electronics.

In a second step, acoustic recordings were made using a pair of loudspeakers equipped first with their original support system, and then with HiFi [1]spikes.

The document is organized accordingly:

- a first part describes the vibration measurements and results
- a second part describes the acoustic measurements and results
- remarks and recommendations are given in the conclusion.

[1] Often referred to as (de)coupling spikes

2 Vibrational response

In this section, we exclusively use vibration instrumentation consisting of a set of three accelerometers, model Brüel & Kjær 4381. The accelerometer was selected for its good sensitivity and its immunity to acoustic pressure fluctuations. They were fixed to the shelves using double-sided tape and a magnetic base. This type of setup makes it possible to obtain representative results up to a frequency on the order of 1 kHz, which is sufficient given the objective pursued here.

In a second step, excitation was applied through the air-borne path (acoustic pressure). This latter quantity is measured by a PCB microphone, model 378C20, whose bandwidth (+/−2 dB) extends from 3 to 16000 Hz. The instrument noise is 16 dB(A), thus entirely negligible here.

2.1 Rack A: vibrational response

In this section, vibration levels at three locations are compared. For tests under acoustic excitation, the pressure signal is measured by a microphone. C1hannel numbering is as follows:

1. Channel 1 (Ain0): acceleration – rack – top shelf (red)
2. Channel 2 (Ain1): acceleration – rack – intermediate shelf (blue)
3. Channel 3 (Ain2): acceleration – floor – shelf placed on HiFi spikes (black)
4. Channel 4 (Ain3): acoustic pressure – center of the room – approximately 1 m above the floor

These locations are visible in the photo below (figure **??**).

Figure 1: Setup – vibroacoustic comparisons

Note that for tests 1 to 6 inclusive, the shelves were unloaded. From test 7 onward, a vinyl turntable was placed on the upper shelf mounted on the equipment rack. From test 13 onward, an amplifier was placed on the shelf located on the floor. The photo above corresponds to this last configuration.

2.1.1 Mechanical response (structure-borne path)

We begin with a recording without sound, simply walking normally in the room. The goal here is to identify "normal" floor vibrations, and in particular the floor's first natural frequency (which will be visible on the rack but for which the rack is not responsible; it merely follows the motion imposed at its base). Time signals are shown in Figure **??** and spectral content in Figure **??.**

We note that the time-domain signals are superimposed, which confirms on the one hand that the floor contacts are "firm", and on the other hand that the racks are rigid up to frequencies well above the floor frequency (which is 22 Hz here, which is rather high, indicating a floor stiffer than average).

2.1.2 Vibroacoustic response (air-borne path)

A first measurement is carried out by speaking normally in the room, with the floor shelf unloaded, the spectral content is shown in figure **??**. Overall, there is no very pronounced difference nor a clear trend between the top shelf (red) and the shelf (blue). Only the shelf placed directly on the floor (black) vibrates less than the two previous ones, but the difference is not very pronounced (on the order of 3 dB on average). Around 100 Hz, the shelf placed on the floor responds significantly more than the other two, for no obvious reason.

Another test (Run 12) was carried out, this time using a musical excitation[2]. Time signals are shown in figure **??** and spectra in figure **??**. We note that vibrations are clearly dominated by the acoustic pressure level in the room.

Levels are relatively comparable at the three vibration measurement points, although the red trace (top shelf) often shows lower levels.

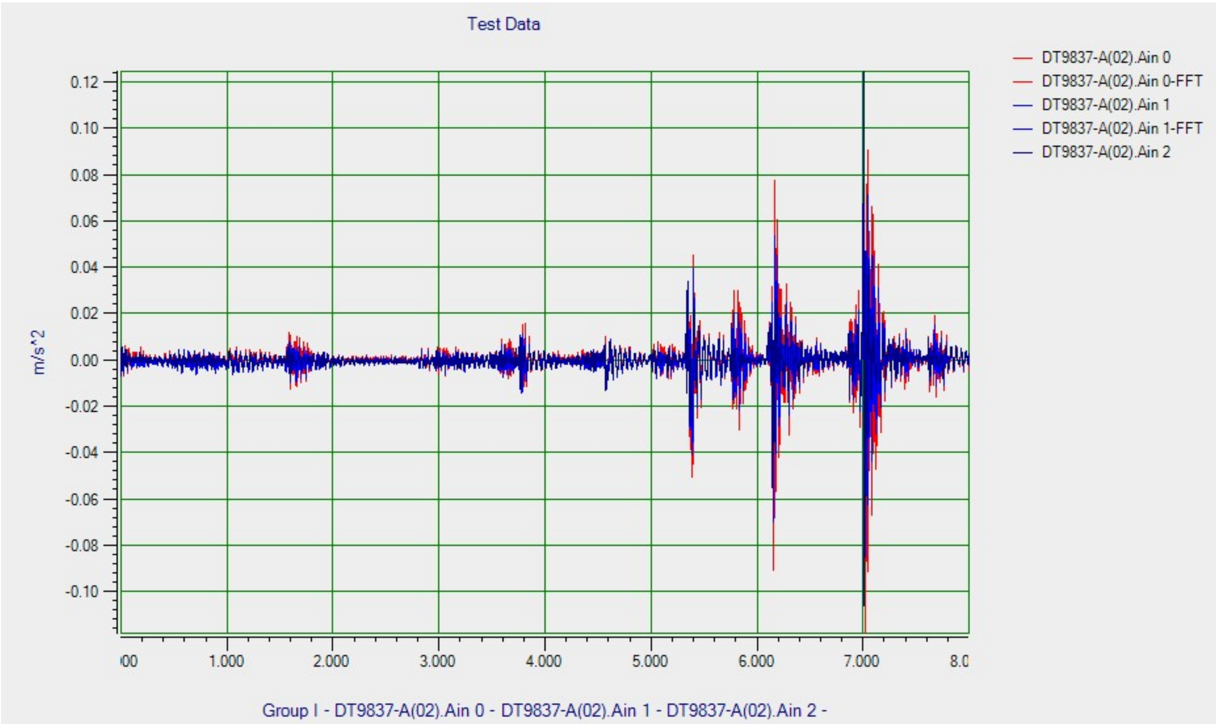
A complementary test (Run 13) was also performed, identical in every respect to Run 12 but placing an amplifier on the turntable on the floor. Time-domain signals are shown in figure **??** and spectra in figure **??**. This addition reduces the acceleration peaks on the floor shelf by about 30% (peak at 80 Hz), and overall brings the three spectra closer.

[2] All measurements were performed using a single track, selected for its rich low-frequency content and impulsive character. It is a remix of the track "Candy Shop" by Blvck Cvbrv.

The findings from these tests are therefore as follows:

- the test was carried out with a floor stiffer than average; it therefore vibrates less
- vibrations of shelves and top shelves coming from the floor are amplified slightly differently
- vibrations of shelves and top shelves coming from acoustic excitation are very similar, although on average the top shelf (red trace) vibrates rather less than the underlying shelf

There is therefore little benefit in changing the rack's support system, since this would only affect structure-borne vibrations, which are not predominant here.



1Figure 2: Run 2 – acceleration time signals

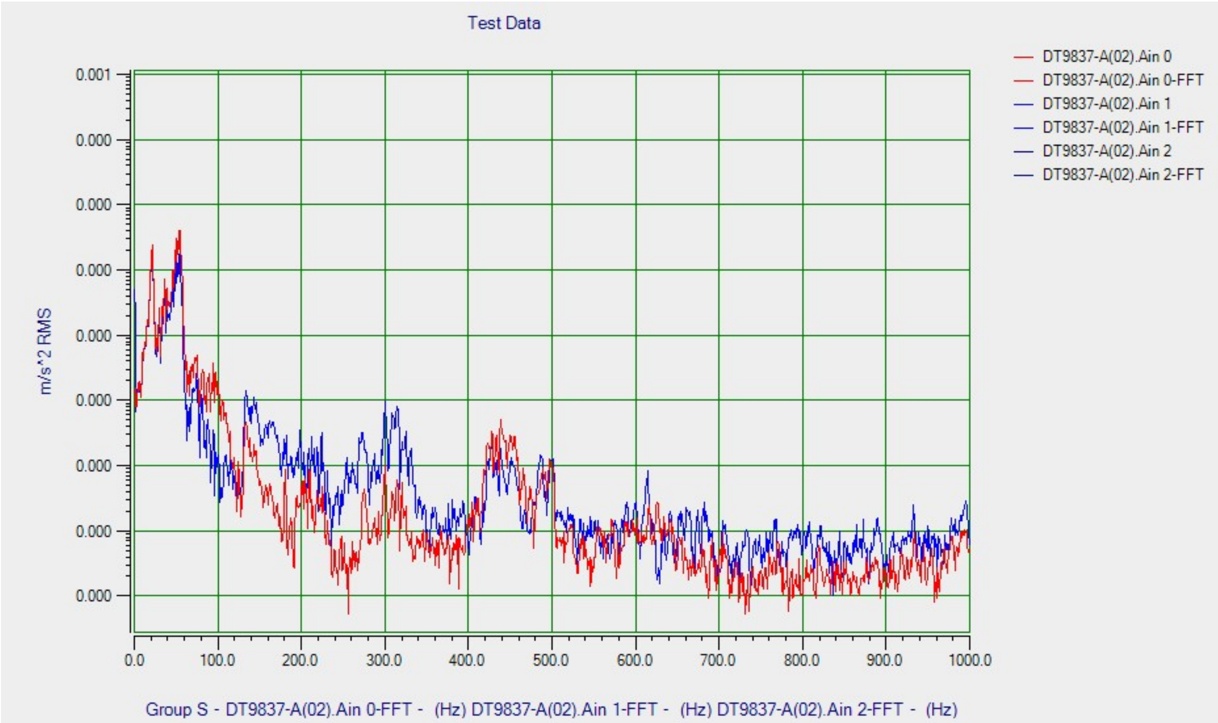


Figure 3: Run 2 – acceleration spectra

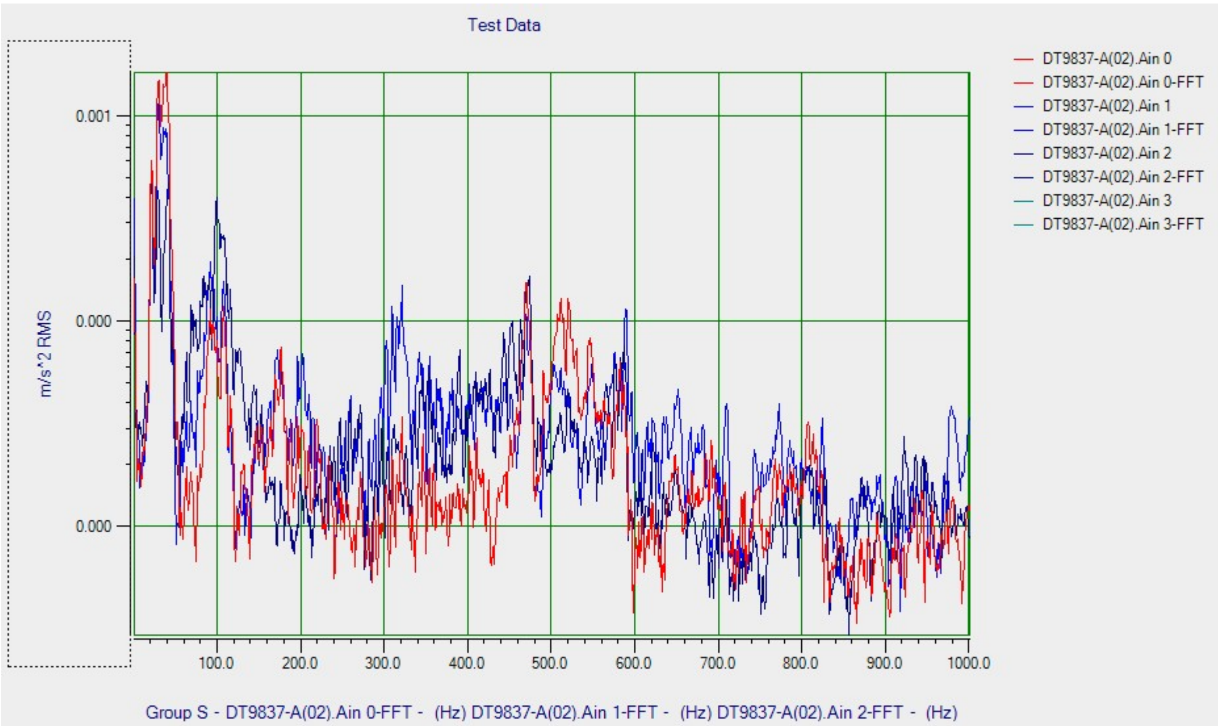


Figure 4: Run 7 – acceleration spectra

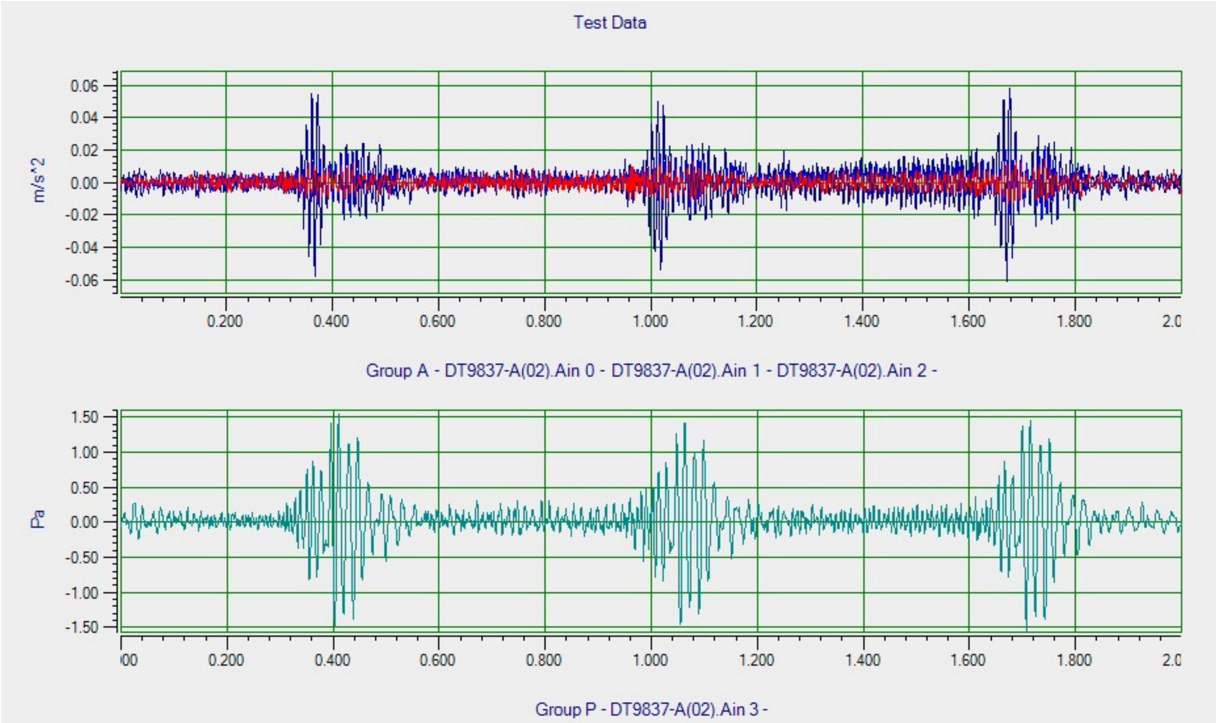


Figure 5: Run 12 – acceleration (top) and acoustic pressure (bottom) time signals

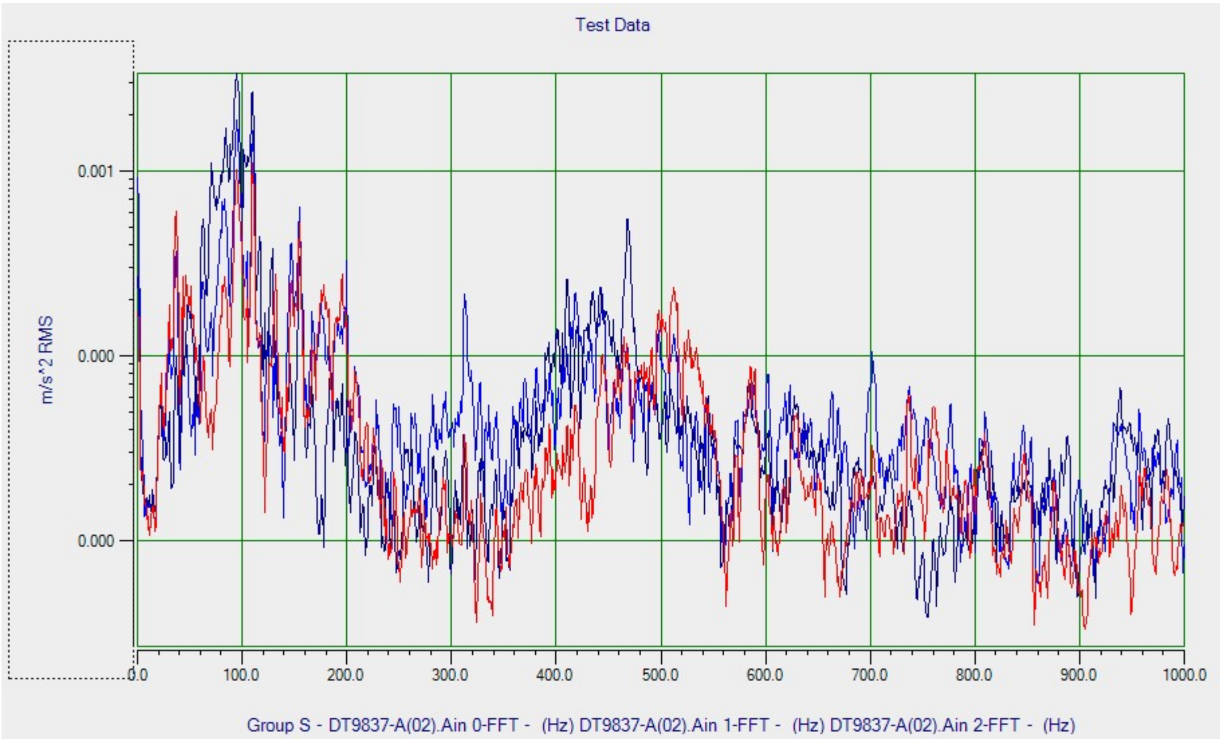


Figure 6: Run 12 – acceleration spectra

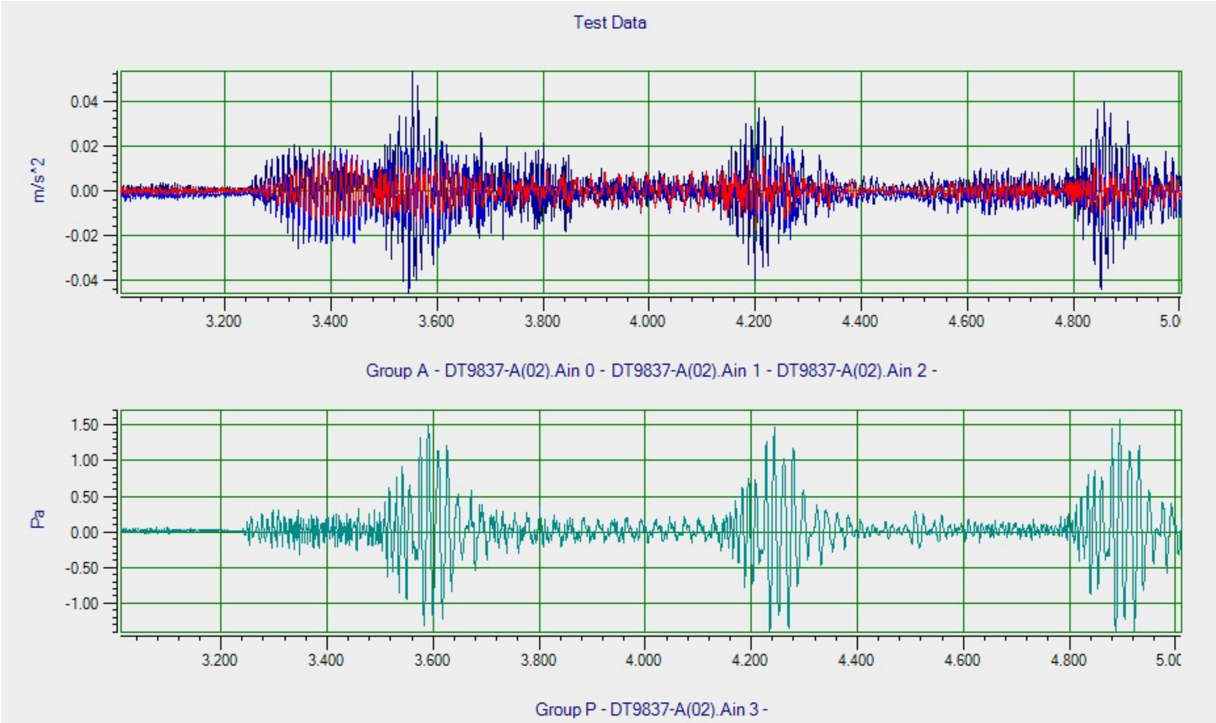


Figure 7: Run 13 – acceleration (top) and acoustic pressure (bottom) signals

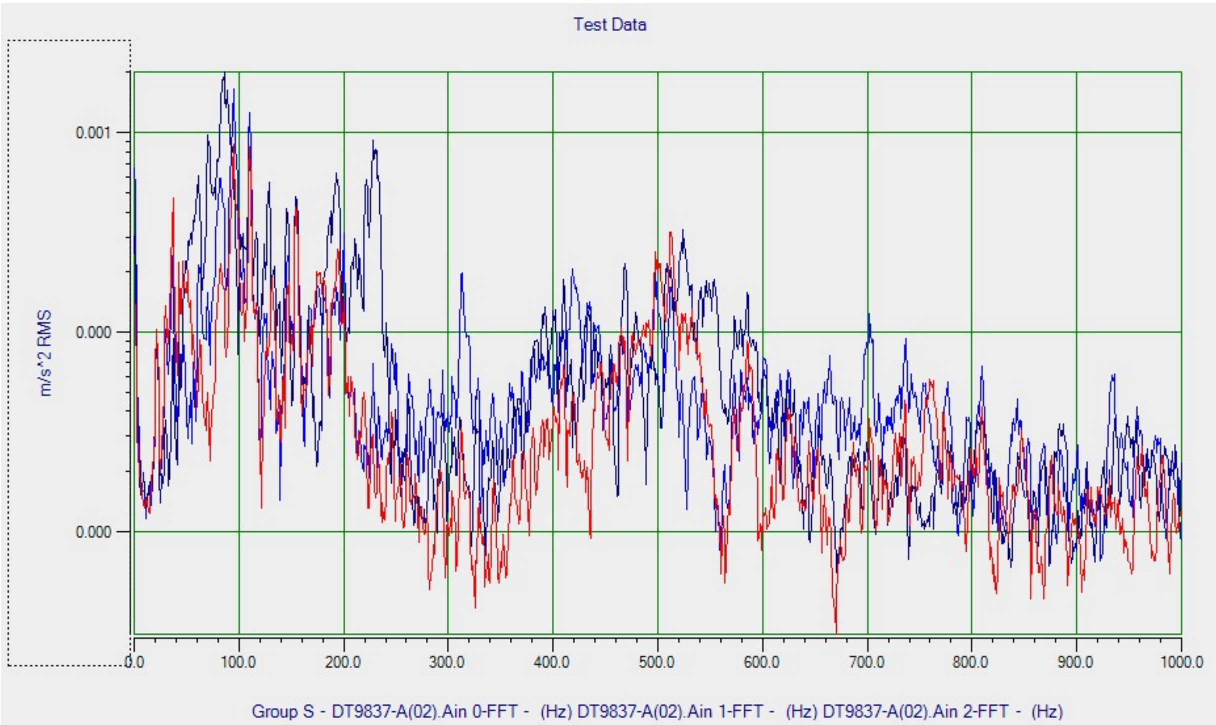


Figure 8: Run 13 – acceleration spectra

2.2 Rack A vs rack B: acoustic response

In this section, we acoustically excite two racks, A and B, shown in the following photos:

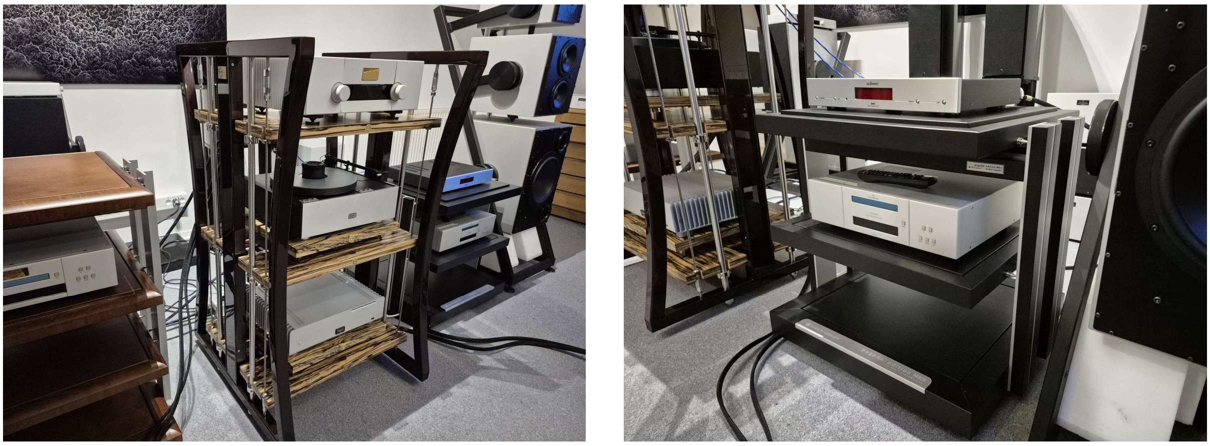


Figure 9: Racks "A" (left) and "B" (right)

The main idea is that since the two racks are arranged symmetrically in the room and relative to the loudspeakers, the acoustic pressure field exciting them is expected to be practically identical.

It is therefore legitimate to compare the vibrational levels on these two racks (levels recorded simultaneously). In both cases, the measurement is carried *out on the shelf, directly under the support of the electronics*. We therefore quantify the vibrations to which the amplification will be subjected.

We record a few seconds and compare the vibration levels again.

Clearly, rack A (red) vibrates significantly less than rack B. This is evident in the time signals as well as across the spectrum (except around 22 Hz, frequencies for which the vibrations correspond essentially to motion transmitted by the floor).

Overall, the difference is on the order of 2 decades, corresponding to about 40 dB in vibration level, except in the 500 Hz 1/3 octave band, where the difference is minimal. This large difference in favor of rack A is explained on the one hand by its open-frame design (allowing pressure to equalize and therefore reducing the resultant mechanical force), and on the other hand by the nature of the shelves, which are both heavier (acoustic mass law) and probably more damped (wood instead of metal).

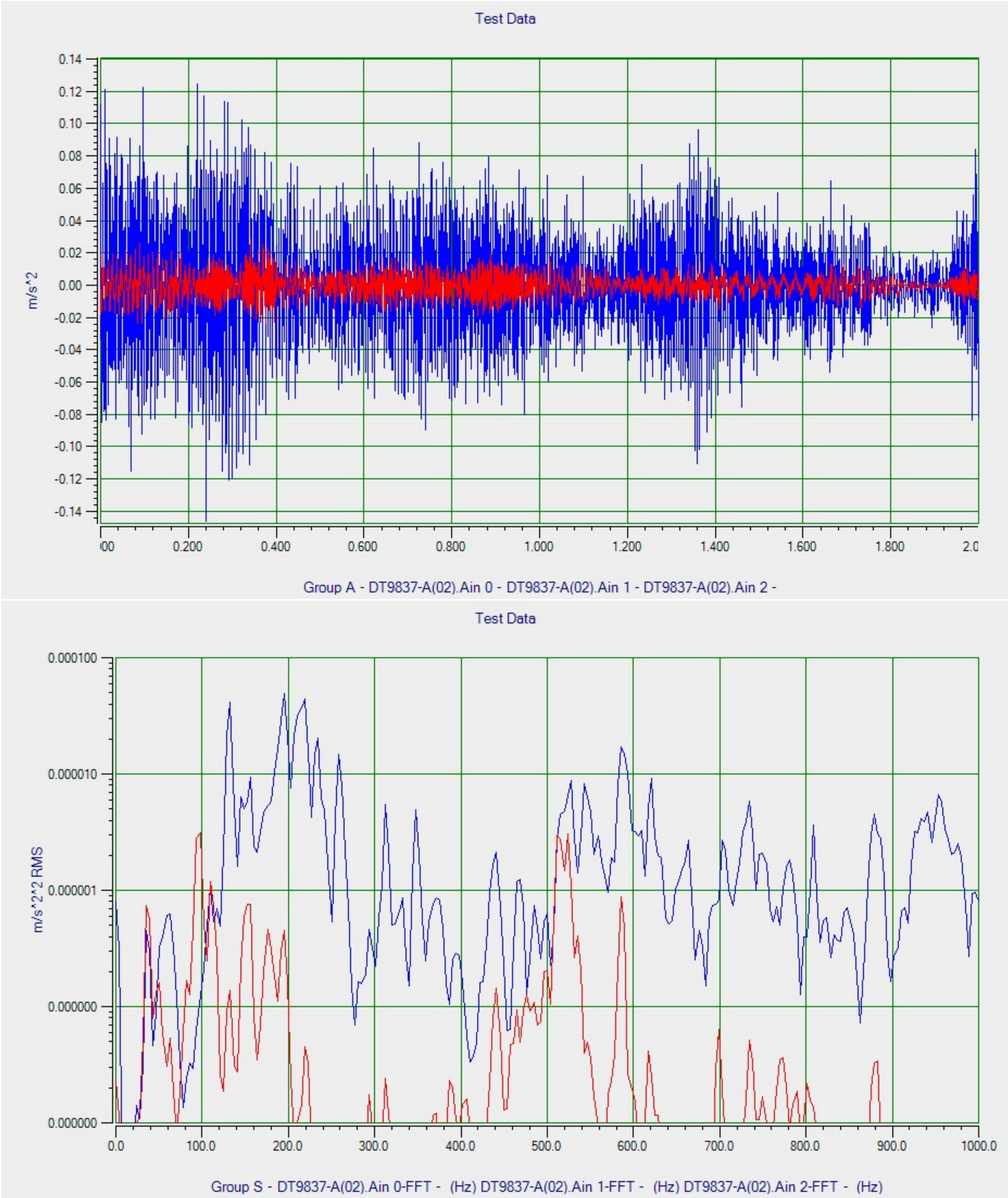


Figure 10: Run 32 – signals (top) and vibrational acceleration spectra (bottom)

3 Loudspeaker support system

In this part, we aim to quantify the influence of the support system on the acoustic reproduction of a pair of loudspeakers. Photos corresponding to the two types of support are given in figures **??** and **??** below:

Figure 11: original support

Figure 12: spike support

The acoustic pressure signal is measured at the same location as previously. Acquisition is performed this time at a high sampling frequency (52.734 kHz), even though in principle we only expect differences in the low-frequency range, or at the extreme limit, in the lower midrange. Resolution remains 24 bits (ENOB on the order of 20 bits).

Each recording lasts 60 s (the full track lasts 2 min 28 s). For better readability, only the pressure time signals corresponding to the first 10 seconds are shown below (figure **??**).

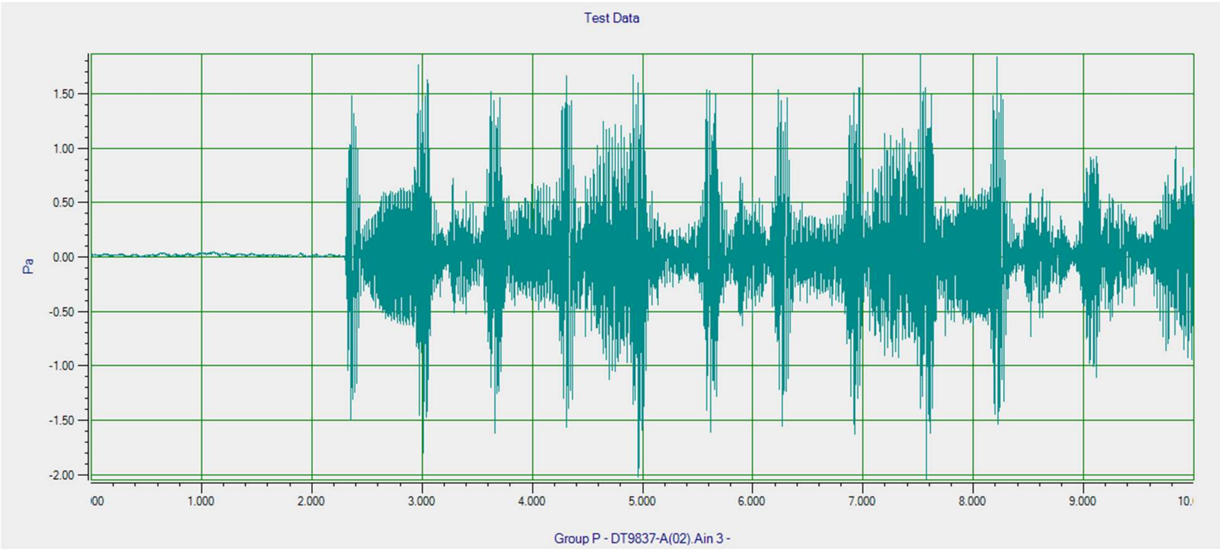


Figure 13: original support

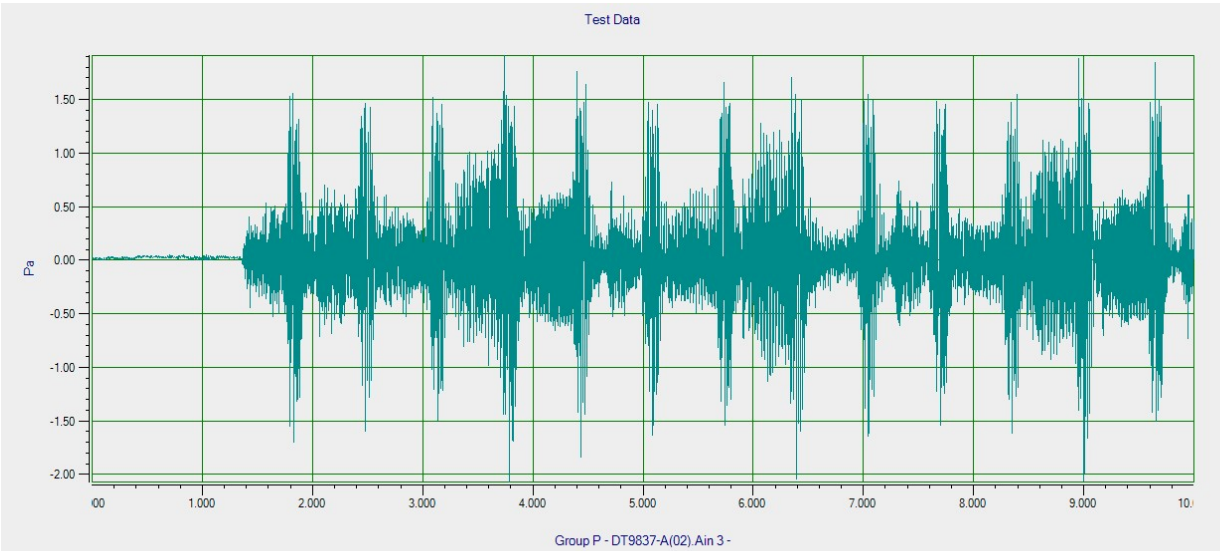


Figure 14: spike support

Since recording is triggered manually, the two recordings are not synchronized. In order to compare the signals, it is necessary to synchronize them. To do so, the signals were replayed in numerical computation software (Octave), and via correlation the offset was identified and corrected. The signals after synchronization are shown in figure **??** below (first 10 seconds only). The beginning of the track is truncated by slightly more than 2 s for the original support.

From these signals, a time–frequency analysis is carried out, consisting simply of short-time Fourier analyses. The result is presented in the form of an acoustic pressure spectrogram, estimated for both configurations.

Results for the full r1ecording (60 s) are given in figures **??** (full bandwidth 0-20 kHz) and **??** (restricted bandwidth 0-1 kHz).

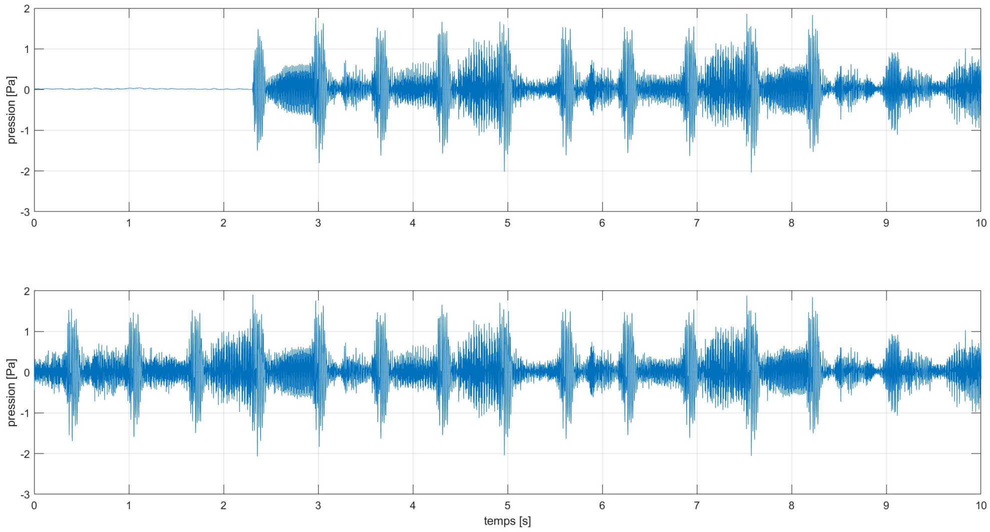


Figure 15: acoustic pressure signals after synchronization

Visually, no difference is detectable. We zoom in on a section without impulses, for which identifying instantaneous frequency content is possible, namely between 41.5 and 42.5 s (spoken voice only). We then focus only on low-frequency content (figure ??) and very low frequencies (figure ??). Only this last figure highlights differences, with the original support being “cleaner” (deeper notches, unchanged peaks).

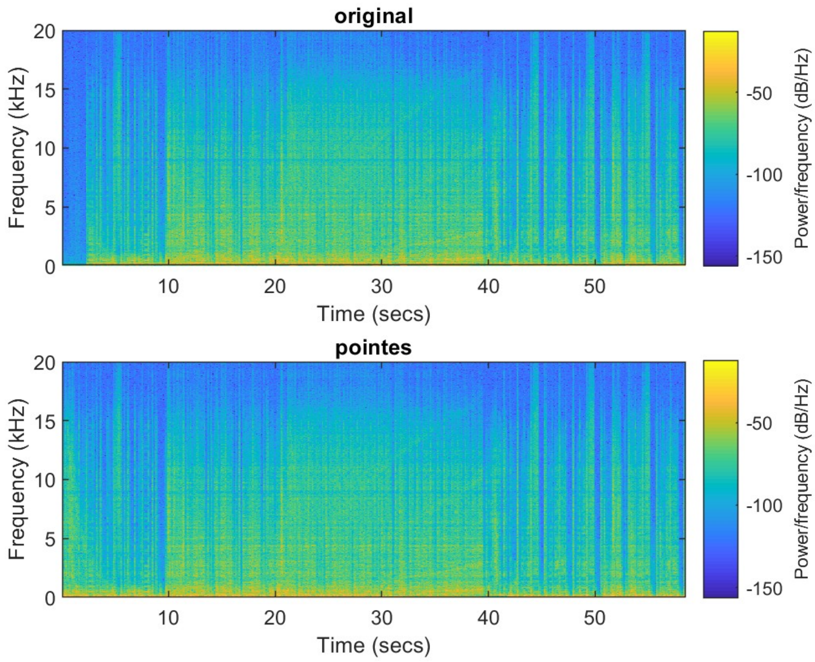


Figure 16: acoustic pressure spectrograms –60 s – [0–20 kHz]

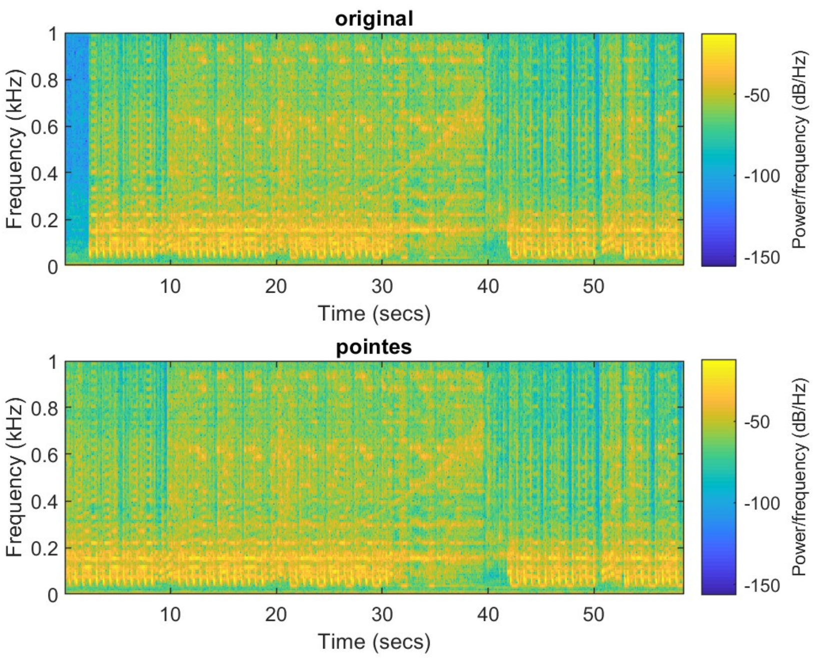


Figure 17: acoustic pressure spectrograms – 60 s – [0–1 kHz]

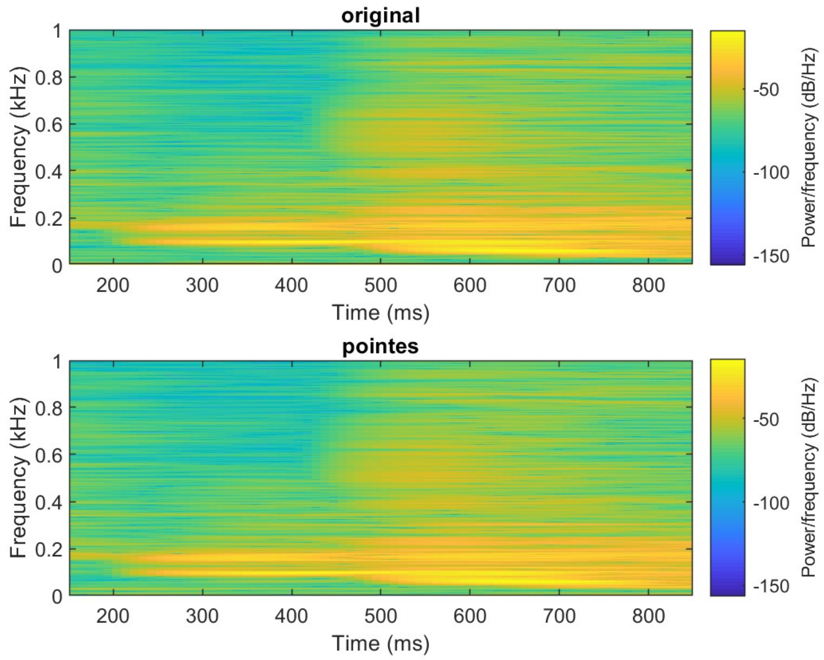


Figure 18: acoustic pressure spectrograms – 1 s – [0–1 kHz]

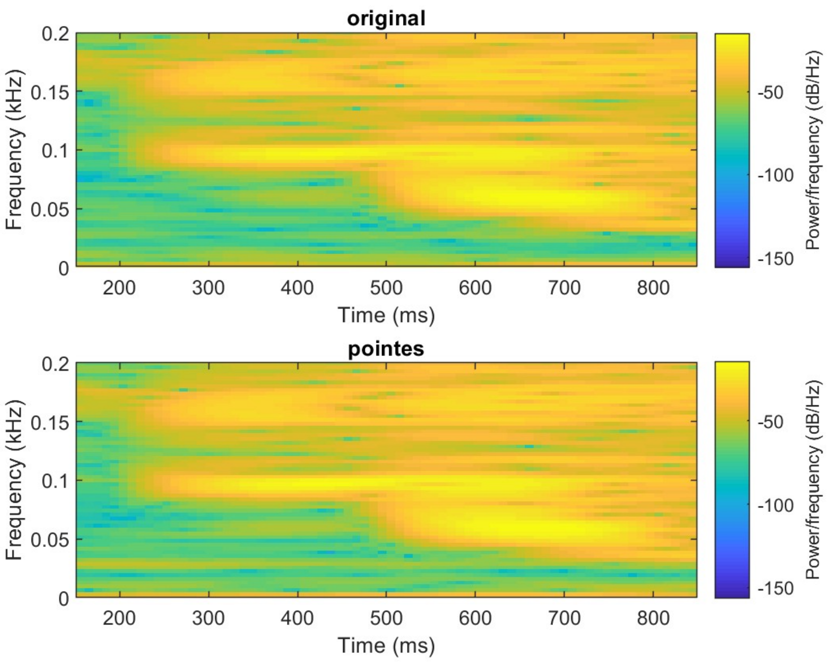


Figure 19: acoustic pressure spectrograms – 1 s – [0–200 Hz]

4 Summary

Following these tests, the following conclusions can be drawn:

- rack vibrations are largely dominated by their response to pressure waves (air-borne path). It is therefore not very effective to work on the support system, but rather on the design.
- in the acoustic domain, there is little difference between vibrations on a shelf and on a stacked top shelf.
- the two racks tested (model “A”, open-frame design, wood/metal/cable composite, and “B”, all-metal, solid side panels) show very different response levels. Rack A (open-frame design) has a much higher surface mass, a smaller area, and higher stiffness; its vibration levels are 20 to 30 dBv lower.
- the influence of the support system on loudspeaker acoustic reproduction was tested, using the Goldmund support method on the one hand and HiFi spikes on the other. The effect is non-existent for midrange and treble, and weak but visible in the extreme low end (between 20 and 200 Hz), without any objective selection criterion to favor one or the other solution, even if the original support yields a slightly better-defined reproduction in terms of instantaneous frequency content.