PROJECT REPORT:	Engineering White Paper Cambre Audio Rack Design Our Client No.: VAN 5Y6 Our File No.: 034205
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November 18, 2004

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Cambre Products Canada
3250 Ridgeway Drive
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Dear Mr. Wiebe:

Re: Engineering White Paper
Cambre Audio Rack Design
Our Client No.: VAN 5Y6
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1.0 AUDIO RACKS

1.1 Controlling Resonance in Audio Racks

Every object has a resonant frequency, including the shelves and vertical supports used in audio racks.

If the resonance of an audio rack can be controlled and minimized, its effect on the audio components it supports should be minimized. Instead of having the rack resonating at a certain frequency, and transferring this resonance to the audio component, the audio rack should provide a stable platform without adding input to the music. Minimizing the resonances of the rack should allow the audio components to produce a more pure, less contaminated sound.

There are two major ways to reduce the resonance of an audio rack. Either the existing resonances can be damped, or the resonant frequencies can be shifted/altered.

Adding damping to an audio rack is hard. While damping an individual speaker woofer or a turntable suspension can be accomplished *relatively* easily, audio components have a lot more mass than a woofer or a turntable platter. Also, the cost to doing this for each shelf makes it a very expensive proposition.

Shifting the resonant frequencies of the shelves of an audio rack out of the audible spectrum is also difficult. There is a huge spread between approximately 20 Hz and 20 000 Hz, the typical range of hearing of a healthy person. The shelves would either have to be incredibly massive and simultaneously not very stiff (to reduce the resonance below 20 Hz), or the shelves would have to be incredibly light and extremely stiff (to increase the resonant frequency above 20 000 Hz). Neither of these two combinations is practical, since more mass usually increases stiffness, and vice versa.

This leaves us with the option of spreading out the potential resonant frequencies of the audio rack such that there are few, if any, large and discreet resonances within the audible band. This should improve the sound, without the extreme cost of sophisticated damping.

1.2 Shelf Design

A simple shelf for an audio rack could be a simple rectangular plate with a given thickness. This shelf would have parallel faces on top-bottom, front-back, and side-side. Standing waves, resulting from either surrounding sounds or the harmonic operations within an audio component transferred through the feet of the component to the shelf, could bounce back and forth between faces, muddying the sound. This is analogous to the standing waves within a listening room. (Although you want some echo and reverberation in a room, otherwise the music will sound 'dead'.)

In the example of an audio rack shelf shaped as a simple rectangular plate, there would be internal standing waves between the top and bottom faces of the shelf, as well as the side-to-side and front-to-back faces.

By altering the shape of the shelf to minimize parallel faces, standing waves within the shelf could be minimized. Now, instead of a few frequencies causing large resonances in the shelf, the significantly-smaller-magnitude resonances would be spread among many more frequencies, with a corresponding improvement to the clarity of the resulting sound.

Also, the entire shelf would have a resonant frequency as it vibrates up and down, supported by the vertical posts of the rack, like a drum skin. This resonance of the entire shelf, which is different than standing waves within the material of the shelf, is primarily influenced by the mass of the shelf, the distance between the shelf supports, and the size and shape of the shelf. It was in attempting to alter this aspect of resonance of the shelves that led to the design of the Camber audio racks.

1.3 Cambre Audio Racks

Experimentation into the design of individual shelves led to adding grooves to the bottom of the shelves. This was originally planned to reduce the mass of the shelf, hopefully altering the resonance of the entire shelf by reducing the mass. The grooves on the bottom of the shelves would not be visible, so the mass and stiffness could hopefully be tuned without changing the appearance of the audio rack.

When a rack with channelled grooved shelves was assembled and the components on the rack began playing music, the improvement in sound quality compared to the non-grooved shelves was amazing, especially in the treble. Everything was more clear.

Since adding the grooves would have reduced mass (increasing the resonant frequency) but also reduced the stiffness of the shelves (decreasing the resonant frequency), only an improvement in the midrange or upper bass, where the resonant frequency of the entire shelf would be situated, was expected. Because there was such a large improvement in the treble, the grooves were, in all likelihood, improving the sound in another way.

We theorized that the improvement in sound was either due to minimizing standing waves between adjacent shelves, or within each shelf. To find out which effect was improving the sound, we did what any good engineer would do: Got out the tools, played with the racks, and listened to some music.

Since the design of the Cambre audio rack was modular, we placed an audio component (CD player) on the second-from-top shelf, and then either left the top shelf installed with the channelled grooves facing downward toward the audio components, or upside-down with the channelled grooves facing upwards. By listening, we could determine which effect was improving the sound.

This was done using three Cambre audio racks that were identical in size. One used shelves without channelled grooves, one used shelves with channelled grooves with the top shelf upside-up, and the third with the top shelf upside-down. The integrated amplifier was placed on the third shelf from the top of the rack with the shelves with channelled grooves with the top shelf upside-up, and the CD player was moved from one rack to another.

We found that the major difference was between the shelves with the channelled grooves compared to the rack without channelled grooved shelves, as was expected. The difference between the shelves with channelled grooves was very small, with the rack with the channelled grooves facing upward having slightly more clarity, although this may have been the result of having the CD player on a rack that did not have the integrated amplifier.

Thus, because there was only a slight difference in sound quality between the Camber audio racks with the inverted top shelf and the normal top shelf, we concluded that the channelled grooves were, in all likelihood, primarily reducing the effect of resonance within the shelves themselves.

The channelled grooves on the bottom surface of the shelves greatly reduced the ability of standing waves to ‘bounce’ back and forth between the top and bottom surfaces of each shelf. Instead of there being one thickness throughout the shelf, there were now a series of thicknesses varying from the total/external thickness of the shelf down to the minimum thickness between the deepest part of the channelled grooves and the top face of the shelf, and everything in between.

While the un-grooved shelf would have had one large standing wave resonance between the top and bottom faces of the shelves, the grooves created more resonant frequencies, and reduced the pronounced effect of the top-to-bottom standing waves in the un-grooved shelves.

It is this reduction in the large standing waves within the original shelves themselves, caused by spreading out the number of frequencies that exhibit resonance, that allows more music to be produced, without the ‘muddying’ of the sound caused by larger, more distinct resonances acting between the top and bottom faces of each shelf. The channelled grooves effectively ‘smooth over’ the resonance, and the music produced is also smoother, as well as being more detailed.

The attempt to minimize resonances within the shelves used in Cambre audio racks extends not only to the channelled grooves on the underside of the shelves, but also to the shape of the sides/edges. There is a bevel on some of the sides which reduces the ability of standing waves to go front-to-back, in addition to curving some of the side edges of the racks. This further reduces the faces of the shelves that can easily permit resonances within the shelves.

The resultant shape of the shelves used in the Cambre audio racks is not only pleasing (in my opinion) aesthetically, but is also designed to minimize the large internal resonances that can exist and accumulate within the shelves of the rack. By ‘massaging’ the shape of the shelves to minimize the sharp distinct resonances, the sound created by the audio components on the shelves is improved, making for better music.

Truly,

Jeff Archbold, B. Eng., M. A. Sc., P.Eng.