Domestic bliss

In the last article in the series **Joseph Curtin** and **Martin Schleske** look at affordable ways to transform your home into an acoustics lab

RIGHT AND OPPOSITE you can objectively evaluate the sound of a violin with measurement systems like this one, which is made of wood and aluminium tubing

All photos: Joseph Curtin

One way to evaluate the sound of a violin is to give it to a good violinist then sit back and listen. The trouble is that good violinists tend to make almost any instrument sound good – it's their job. Instinctively, they compensate for unevenness, coax out hidden reserves of power, smooth over rough spots and bring everything together with vibrato. They impose their own voice on an instrument, so that what you hear is not so much the violin as violin-playing – a kind of magic trick they do, using the instrument as a prop.

Violin makers are used to dealing with all this, but most would welcome some sort of objective scale for violin sound – some way to measure what it is that violinists and their audiences most want from an instrument. Earlier in the Sound Waves series we saw that two much-sought-after qualities – projection and what might be called 'old Italian tonal balance' – are largely determined by an instrument's ability to concentrate sound into two particular frequency regions. This ability can be assessed by measuring frequency response; and here we look at measuring it in a workshop setting and then consider a way of plotting frequency response so as to give a quick sense of overall power and tonal balance.

The pictures show a workshop-built measurement set-up using an impact hammer (see The Strad, April 2004). It is built with plywood, scraps of hardwood and aluminium tubing – held together by bolts and wing nuts. This makes it easy to dismantle and transport, assuming that it is often more feasible to bring the equipment to a valuable violin – in a museum or a soloist's hotel room, for example – than the violin to the equipment. The laptop computer runs SpectraPLUS on a Windows 2000 operating system. While almost any computer will do the job, more recent vintages provide better support for devices using a USB interface – in this case, the sound card.

Laptops are typically supplied with very basic sound cards and the inside of a computer is a noisy environment, electrically speaking, so external sound cards are generally used for high-quality audio recording and measurement. Fortunately, external cards are widely available in all price ranges. The one pictured, a Creative MP3+, connects to the USB port, which also powers the device. The card does not provide the phantom power needed by most

LEFT this measurement set-up is small enough to be used in a house or violin workshop

BELOW the instrument is supported by thin elastic thread, to isolate it from the rest of the equipment

condenser microphones, but otherwise functions admirably – and at around €35 the price is hard to beat. Details of all the component manufacturers are given on page 700.

The microphone is by Earthworks – a calibrated, omni-directional, measurement microphone with an impressively flat frequency response across the violin's range. Because it runs on an internal battery it does not need phantom power, and its switchable 14dB preamp gives the signal a sufficient boost to feed directly into the line input of most sound cards. The microphone can be moved up and down the support rod, which in turn can be moved along the aluminum rail, over a range of about 600mm from the centre of the instrument (here defined as a vertical line ascending through the endpin). A self-adhesive scale on the rail makes it easy to establish the exact distance between the microphone and the instrument. The instrument itself is supported from underneath and at the neck by thin elastic thread, available from sewing stores.

The impact hammer is the smallest model made by PCB Piezotronics and together with a power supply and cables, it costs about €1,000. The hammer has been mounted on a ball bearing to ensure a free swing along a consistent path. Flicking the back of the hammer with your fingertip will swing it towards the violin bridge. If the pivot point is placed about a centimetre behind the hammer shaft, the hammer will hang at about 30 degrees from the vertical and 'park itself' clear of the bridge after impact. In practice, aligning the tiny hammer tip with the corner of the violin bridge can be ticklish; in order to speed things up, the whole assembly is attached to an adjustable X–Y–Z mount, using three linear slides from Edmund Optics, costing about €100 each. The violin and the impact-hammer assembly can be rotated through 360 degrees with respect to the microphone.

A microphone distance of around 500mm is large enough to avoid most near-field cancellation, and yet close enough that sound coming directly from the violin is significantly stronger than the sound reflected by the room surfaces, at least in a normally reverberant room. Because of the violin's directional characteristics, a number of readings must be taken around the instrument in order to get a reasonable estimate of the total radiation. In an anechoic chamber, a great many would be needed, but in normal environments the room reflections help moderate the directionality. We have found that six readings, taken at 60-degree intervals as the instrument is rotated with respect to the microphone, are usually sufficient.

Room acoustics are probably the biggest obstacle to getting clean measurements. One way around this is to build an anechoic chamber – not unfeasible if you have the space. Something the size of a pantry or walk-in closet could work for violins and violas. Most professional chambers use foam wedges to absorb sound, but acoustic foam can be prohibitively expensive. Fortunately, there are products that work very well at a fraction of the cost. Owen-Corning type-703 fibre glass panels are semi-rigid boards available from building suppliers. Four-inch thick panels attached to a wall provide virtually perfectly absorption to below 200Hz – adequate for violins and violas, remembering that almost no sound is radiated below the frequency

LEFT the measurement set-up is mounted on a trolley and can easily be wheeled out of the way

of the Helmholtz resonance. Cellos and basses, on the other hand, require larger chambers and thicker absorbent layers. Master Handbook of Acoustics by F. Alton Everest offers an excellent non-technical account of room acoustics and much practical advice about the treatment of rooms for a wide variety of purposes.

Even without an anechoic chamber, several things can be done to reduce the effect of room acoustics: absorbent panels or acoustical tiles hung from the ceiling can minimise reflections; soft wall hangings and upholstered furniture also help; alternatively, absorbent materials can be hung to form a tent around the measurement area. As long as the apparatus is kept in the same position in the room, meaningful relative measurements are possible. But perhaps the most practical approach for violin makers is to repeat the six-reading measurement cycle in a number of positions in the room and then average the results. It is true that the overall amplitude of the measurements will be increased by the room reflections, but most of the peaks created by certain room resonances can be smoothed out this way. We have found that 20 measurement cycles, with both the instrument and microphone rotated 18 degrees with respect to the room for each cycle, gives a reasonably repeatable measurement from room to room. This does mean 120 separate readings, but remember that an impact hammer reading takes only a few seconds and the software takes care of the averaging.

It is easy to become discouraged by the many obstacles on the way to getting clean measurements – or to fall into a never-ending search for the perfect measurement system. There is no such system. It is simply a matter of finding the kind of workable compromise that allows you to keep moving forward. While a complete measurement system may be out of the range of an individual maker, makers' groups and associations might invest in the equipment and organise workshops on its use. Figure 1 shows the frequency response for the 'Schreiber' Stradivari violin, measured in a workshop using the 120-reading approach suggested earlier. The graph shows a jagged line typical to all violins. If you are looking for a detailed account of how sound

Useful software

An acoustical-analysis program is needed to compare the impulse from the hammer with the signal from the microphone and present the results graphically. A variety of programs can be downloaded free from the web. These are mainly single-channel analysers and, though useful for plate tuning and many other measurements, two channels are needed for impact hammer measurements – one each for hammer and microphone. SpectraPLUS is a mature program for the PC platform. It is capable of a wide variety of measurements, including real-time spectrograms and room acoustics, and costs about €500; Spectrafoo is a similar program for the Macintosh. WinMLS, a program written by Norwegian researcher Lars Morset, was not available in its latest form when this article was going to press, but it promises to be relatively inexpensive (less than €200) and comes with a number of pre-installed configurations for violin measurements, including impact hammer, bridge tuning and plate tuning. Morset has also developed a system for measuring frequency response by using a coil to drive a tiny magnet attached to the bridge – well worth closer examination. Details of this can also be found on his website. Cool Edit from Syntrillium Software, for many years one of the least expensive two-channel analysis programs, was recently acquired by Adobe Systems and is now available only in a more powerful and expensive ($299) version called Adobe Audition.

Figure 1

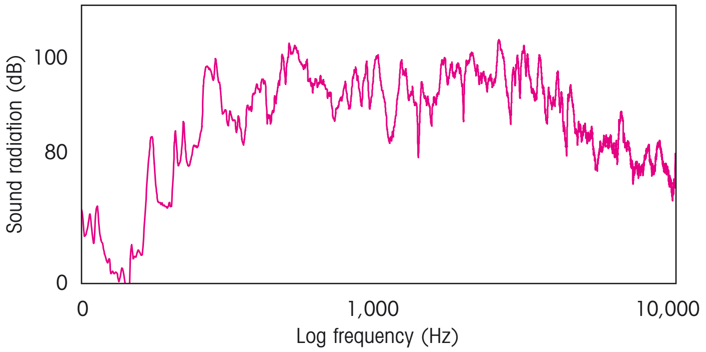


Figure 2

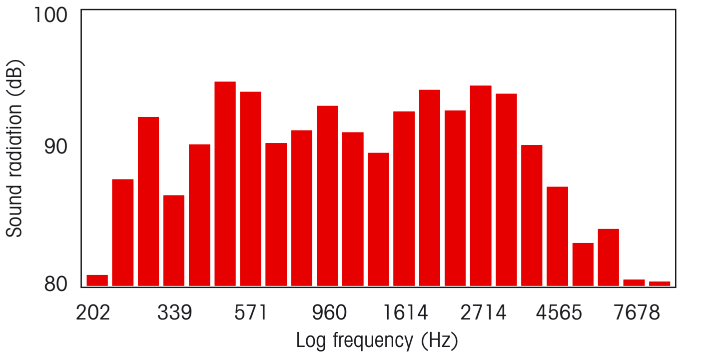
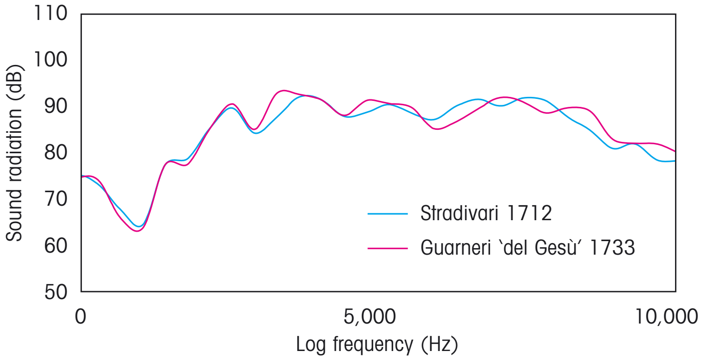


Figure 3



Diagrams: Martin Schleske

output changes with frequency, you need look no further, but if you want a quick sense of how the instrument sounds, you may feel you have been given a satellite photo when you asked for a road map. The information is there, but it is buried in the detail. The quality parameters devised by Heinrich Duennwald (The Strad, January 2004) can be used to extract useful information – in fact to separate the old Italian instruments from the others, at least on a statistical basis. Duennwald used some fairly sophisticated analytical tools, however, and there is a simpler approach.

Acousticians have long employed third-octave bands when looking at everything from room acoustics to speech defects. While the human ear is capable of the subtlest discrimination in the pitch of notes, third-octave bands roughly capture the resolution with which the ear perceives tone colour – the width of the brush-stroke, so to speak. In Figure 2, the response curve of the violin is plotted as a third-octave bar chart, the height of each bar representing the total energy in each frequency band. Though much detail is lost, we are able to get a quicker sense of the general distribution of energy.

The contribution of each frequency region to tone colour is indicated above the graph. When several of these graphs are overlaid, it becomes difficult to sort out one from the other. For this reason we prefer to plot the data as a series of super-imposed smooth curves.

In figure 3, a smoothed third-octave graph of the 'Schreiber' Stradivari is overlaid with that of a 1733 Guarneri 'del Gesù'. Both the Strad and the 'del Gesù' show the two broad peaks typical of old Italian violins – the difference between their curves reflects their individual tonal characters. It is a mistake, however, to assume that two instruments with identical third-octave profiles would sound the same. Firstly, the ear is highly sensitive to sounds in the 2,000–4,000Hz band, so small differences of emphasis within this region are likely to be tonally significant. Secondly, this kind of representation suppresses any sense of the 'spikiness' of the response curve – the very spikiness which contributes to the amplitude modulation of harmonics during vibrato (The Strad, October 2003), an important element of tone colour and, in all likelihood, projection.

Science is still some distance from a complete understanding of the violin, but it already offers violin makers many unprecedented insights into the inner workings of the instrument. It also offers measurement tools that enable meaningful and relevant comparisons between new instruments and those of past masters. Should makers today try to emulate the response curves typical of the old Italians? Should we try to match or even exceed their overall power? Well, it's what good violinists want.

CONTACTS

Earthworks
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PCB Piezotronics
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SpectraPLUS
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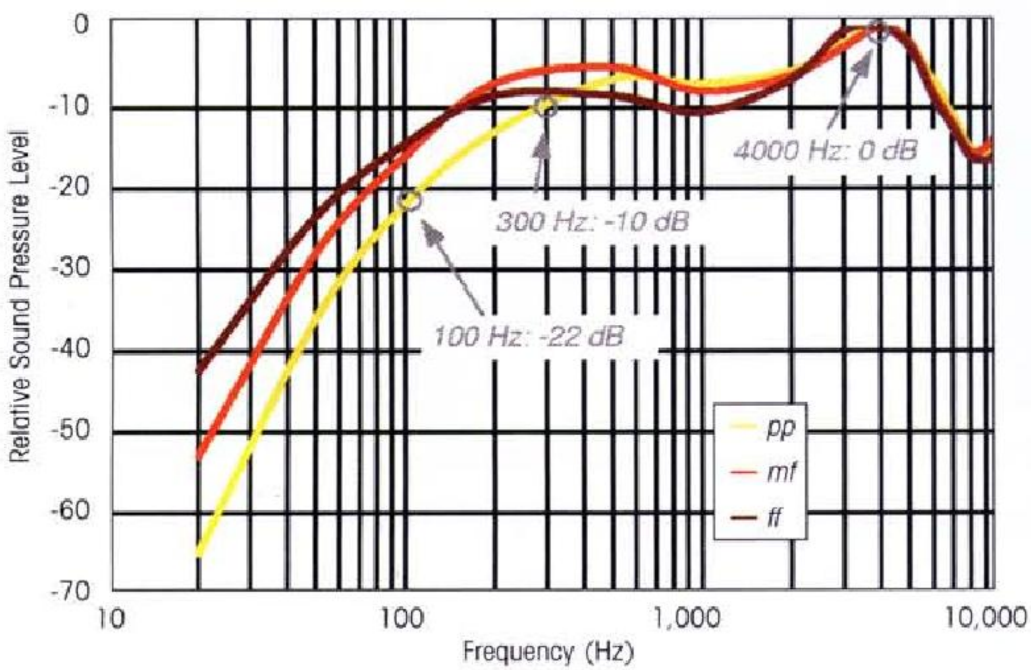
Spectrafoo
www.spectrafoo.com
WinMLS
www.winmls.com
Adobe Audition
www.adobe.com

Corrections to Curtin/Schleske articles
“Can You Hear Me?” and “Domestic Bliss”

Can You Hear Me?

The Strad, October 2003

Figure 3



ABOVE the ear’s sensitivity to sound varies across its frequency range. Each curve in figure 3 displays a constant perceived loudness – *pp*, *mf*, or *ff*

up when the competition arrives?’ After all, being heard in a large hall over a full orchestra goes to the heart of what most violinists mean by projection.

If we think of the concert hall as a kind of

Figure 3 caption should read as follows:

“The ears sensitivity varies across its frequency range. The yellow, red, and brown curves represent perceived loudness (in response to sounds of equal intensity) as a function of frequency. Thus at pianissimo levels, to produce the same sensation of loudness at 100 Hz as at 4,000 Hz, it would take an increase in sound level of 22 dB. Note that the curves are normalized to an arbitrary relative sound level of 0 dB at 4,000 Hz.

Domestic Bliss

The Strad, July 2004

Figure 1

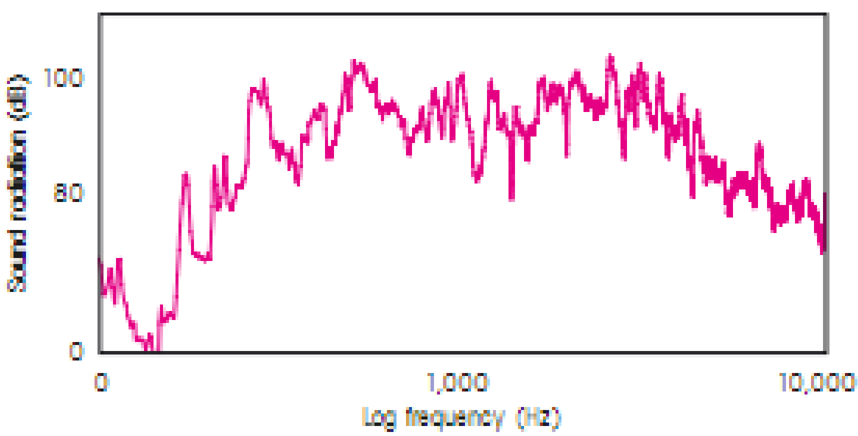


Figure 2

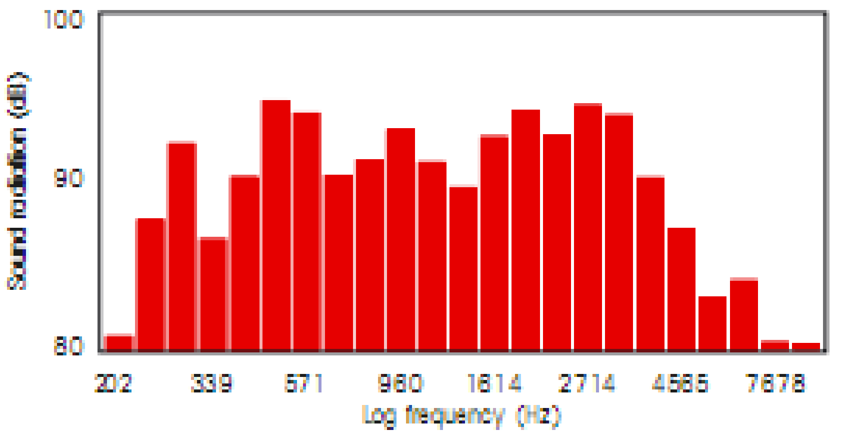


Figure 3

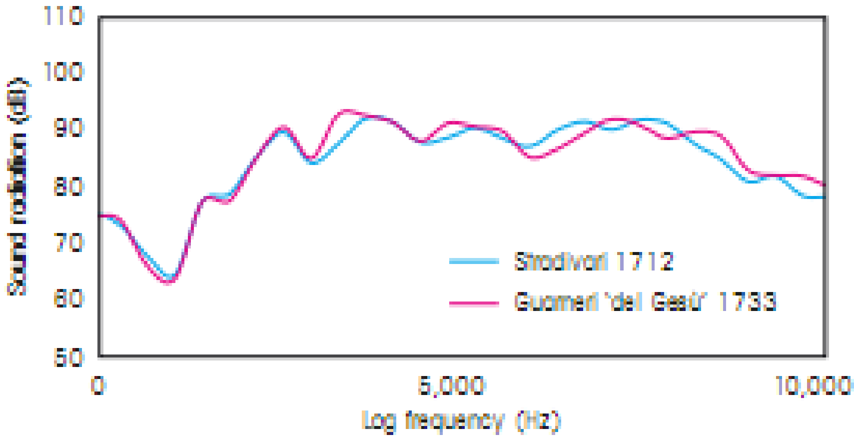


Figure 3: frequency in the center of the horizontal axis should be 1,000 Hz, rather than 5,000 Hz.