Violin Acoustics – Overview

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This is the first in series of articles on the topic of violin acoustics. As Librarian, I can attest to an overwhelming volume of material that has been written on the subject over many years. My intent is to distil down to the most important issues that affect sound, with special attention to how a maker might measure it and how construction modifications might control it. I'll try to keep technical jargon to a minimum, but some will be required.

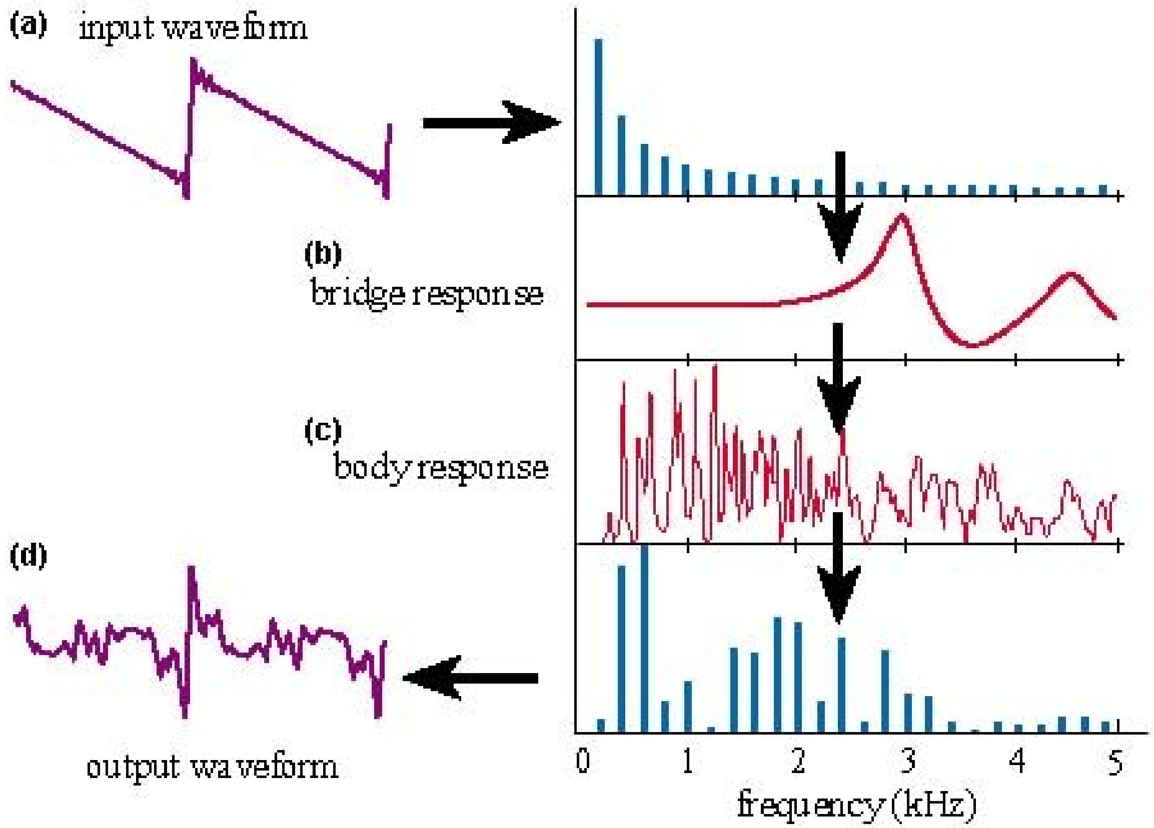
An excellent treatment of the basics can be found at: http://www.physicscentral.com/explore/action/fiddle-1.cfm, from which the first figure is taken.

A bowed string creates a sawtooth force input to the bridge, shown as the (a) input wave form. This can be mathematically decomposed (via Fourier transform) into series of harmonics (shown at the right of the waveform), with the height of the column indicating the energy at each frequency.

The first modification to the sound comes from the bridge, which acts as a "low pass filter." This means that below the resonant frequency of the bridge (bending at the waist, about 3000 Hz), input forces are passed through unchanged. Around the resonant frequency of the bridge, the forces are amplified, and above that they are reduced.

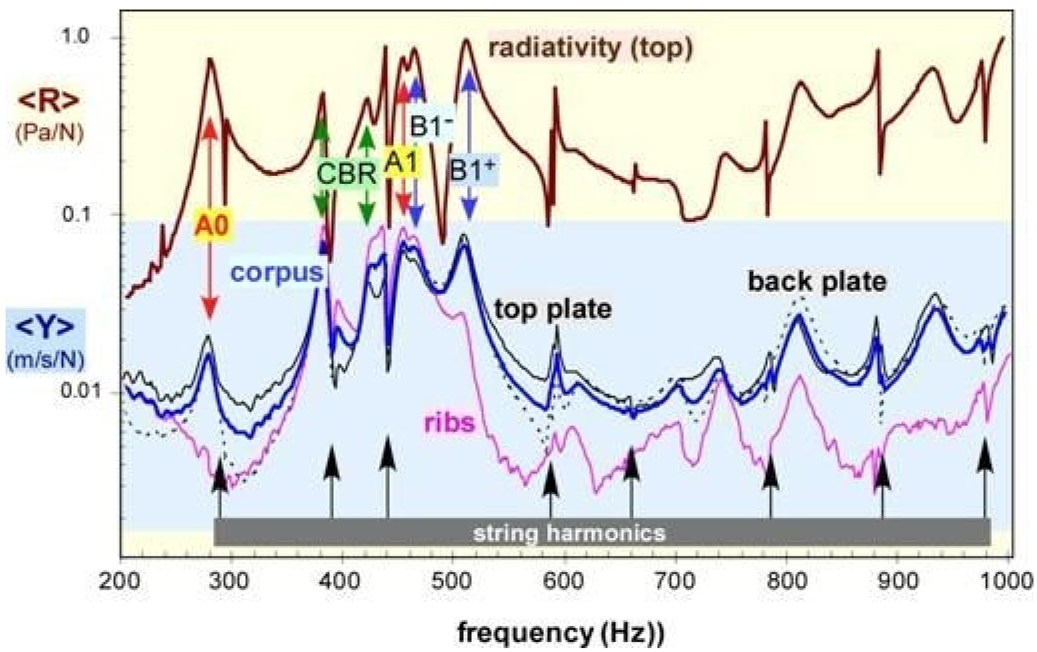
The next and most complex modification to the sound comes from the violin body, where structural and air vibrations act to amplify or attenuate various frequencies.

The resulting sound is simply the cumulative effect of the bridge and body modifications to the string input. OK, there's a lot more to it than that, but this is the main idea.



I'll skip over the bridge for now, and look into the body response in some more detail.

Here's a plot I stole from a paper by George Bissinger, located at http://www.acoustics.org/press/153rd/bissinger.html. It shows the body response (and some other stuff) in the low frequency range, with the major vibration modes identified. The body response is the top line of the plot.



The following definitions are lifted from the oberlinacoustics.net website:

A0 … Usual abbreviation for the "air mode" of a violin or other instrument. This mode is a Helmholtz resonance, involving air flow in and out of the f-holes, but modified by the fact that the walls of the box are not rigid so that some breathing motion of the box also occurs. A0 is usually found around 280 Hz in a violin.

CBR … Acronym for a vibration mode of the violin body, coined by Bissinger: "C bouts rhomboidal". This is a mode usually in the general vicinity of 400 Hz for a violin, which shows up in input admittance measurements but is not a strong radiator of sound. This mode was labelled by Jansson "C2", and by Marshall "Vertical translation of C bouts".

A1 … half-wavelength fitting into the length of the body cavity. It is usually around 480 Hz in a violin. It has a nodal line near the bridge, and is therefore not driven very effectively by the strings.

B1-, B1+ … Usual names for two strong resonances of a violin body, responsible for a lot of the sound radiation at low frequencies. Between them they are responsible for what older literature called the "main body resonance". Other labels for these modes are P1 and P2, or T1 and C3. For a violin, B1- is typically found around 450-480 Hz, B1+ around 530-570 Hz.

The A0, B1-, and B1+ are the strongest sound producers, and are often referred to as the “signature modes” of a violin.

To see how the violin body actually moves and flexes at these resonances, I’ll refer you to the Martin Schleske website, which has a huge wealth of information. The area of vibration animation is specifically at: http://www.schleske.de/en/ourresearch/introduction-violin-acoustics/modal-analysis/animation.html

This is all interesting to a researcher or theoretician, but a violin maker would want to know: what is the goal for the response, and how do you get it? That is subjective, but I'll offer a few opinions.

If you want to make an instrument sound and behave like a great violin, you have to pretty much get the frequencies and amplitudes where they are in great violins. Resonances that are too strong tend to be prone to wolf notes; resonances at unexpectedly low or high frequencies might sound too dark or thin, and a violinist may find it to require a different playing technique. I think the idea would be to get everything (in this low frequency range) as even as possible.

I can think of no recipes to get to a desired response; an educated trial-and-error method seems necessary. Build one, see what you get, then make adjustments to the next one. In general, frequency can be raised by removing mass from areas of high motion, and/or stiffening areas of high bending… and the opposite would lower the frequency. Amplitude should increase if you increase the area moving and/or decrease the mass in motion.

Now, for the big caveat: this is just a small part of the sound spectrum of the violin, and once you start playing on the E string, none of the resonances covered so far have any influence. The higher frequency range is where the ear is more sensitive, and this is where I think the truly great instruments perform best.

To be continued.