

BRIDGE TUNING: METHODS AND EQUIPMENT

Joseph Curtin
3493 West Delhi, Ann Arbor, MI 48103
violins@josephcurtinstudios.com

Abstract

The frequency of a violin bridge's lowest lateral resonance to some extent controls the brightness of the instrument. This frequency can be measured by holding the bridge feet in a relatively massive clamp, touching a piezoelectric sensor to an upper corner, and then "plucking" the bridge with a fingernail. The signal from the sensor is sent to a computer equipped with a soundcard and acoustical analysis software. This system enables the violinmaker to monitor the lateral resonance frequency of the bridge as it is tuned by removing wood from particular areas.

Violinmakers know that tiny changes to an instrument's bridge can make large differences in its sound. In recent decades, researchers—especially Erik Jansson—have shown the importance of the bridge to the violin's treble response [1]. They have focused mainly on the bridge's lowest in-plane resonance and the extent to which it affects—or perhaps even creates—the so-called Bridge Hill [2]. The Bridge Hill is a cluster of strongly radiating resonances in the 2,000 to 5,000 Hz range of the violin's response curve. Its characteristics determine the instrument's treble response, and thus its brilliance and projection. In the past few years, researchers have considered how the mass of the bridge, as well as the spacing of its feet, affects the Bridge Hill.

By "bridge-tuning," I refer to the process by which violinmakers consciously adjust the bridge resonance in order to optimize the sound of an instrument. In this paper I will give a brief overview of the acoustics involved and then present an inexpensive computer-based method for measuring bridge frequency in the workshop.

The Bridge as a Filter

The upper portion of a violin bridge is divided from the lower by a distinct waist. This creates the conditions for a resonance: the waist acts as a spring, the upper portion as a mass. There are several ways the upper portion can vibrate: toward and away from the fingerboard, for example, or in a twisting motion. Because the strings exert primarily a side-to-side force on the bridge, we are concerned here with the bridge's lateral, in-plane mode pictured in Fig. 1. This mode, which I'll refer to as the "bridge resonance," is the bridge's lowest in-plane resonance, though it typically occurs at the relatively high frequency of ~3,000 Hz. The actual frequency is determined by the relationship between the mass of the top portion and the stiffness of the waist. A more massive top will lower the frequency, and a lighter one will raise it. Similarly, a stiffer waist will raise the frequency and a less stiff one will lower it.

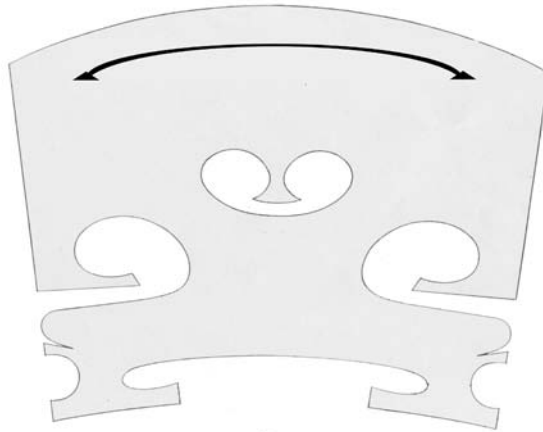


Figure 1. The bridge's lowest in-plane resonance: the top portion of the bridge rocks from side to side. The restoring force is provided by the stiffness of the waist.

The acoustics are, briefly, as follows. Well below resonance frequency, the bridge acts as a rigid body, allowing the strings to act directly on the body. At resonance, the bridge powerfully reinforces transmission of vibrations between strings and body. Above resonance, the bridge tends to decouple the strings from the body, thereby reducing the transmission of string vibration. The bridge thus acts as a *low-pass filter*, tending to cut off string vibrations that are higher in frequency than the bridge resonance. This provides the maker with a kind of treble control knob, which can be turned up or down by raising or lowering the

resonance frequency.

We must add that the interaction of the bridge with the strings and the violin body is complex and not yet fully understood. The bridge resonance, described here in isolation, to some extent disappears into an intricately coupled series of resonances. Still, the simplification is useful inasmuch as it provides a framework for a useful workshop practice.

In Practice

The effective mass of the upper portion of the bridge is determined by such factors as the density of the wood, the height of the bridge, its overall thickness, the position and size of the heart, and the size of the cut-outs. The stiffness of the waist is determined primarily by its width (typically, from 15 to 16 mm), but also by the wood properties, the thickness of the bridge, and by the geometry of the legs and supporting structure.

Narrowing the waist and/or leaving the top portion heavier will reduce the resonance frequency. Leaving the waist wider and/or reducing the mass of the top portion will increase the frequency. The frequency is only slightly sensitive to the thickness of the waist (measured from the front to the back of the bridge).

To get a sense of the effect of a large increase in bridge frequency on the tone of the instrument, insert two tiny wood wedges of spruce into the edge of the bridge cut-outs, thus raising the resonance far beyond its normal frequency. The increased brightness/harshness of the tone represents the upper limits of bridge tuning. Progressively narrowing the waist will illustrate the effects of gradual downward shifts of frequency. Another simple experiment is to stick tiny pieces of modeling clay to the top of the bridge and listen to the changes in tone. In this case, the mass of the upper portion goes up, while the stiffness at the waist remains the same. The result is a reduction in frequency.

Discussion

Violin bridges are typically tuned at ~3000 Hz (the professionally cut bridges I have measured fall between 2,800 Hz and 3,400 Hz), which happens to be the approximate peak frequency for normal hearing sensitivity. This tuning tends to happen naturally with normal workshop practice, but it can be consciously controlled by the maker.

Though research has focused primarily on the frequency of the resonance, a number of years ago I began exploring effects of varying the mass of the top portion of the bridge while keeping the frequency constant. Imagine two bridges tuned to the same frequency, but one weighing twice as much as the other. Clearly,

they are not acoustically interchangeable. As the mass goes up, more and more of the string energy is reflected back into the strings, rather than being transmitted to the body. An extreme case is the practice mute. In my experience, effective mass is as important as frequency to the instrument's sound. I find that low-mass bridges tuned to the high end of the frequency range (~3,300 Hz) can work well for instruments used in solo work. When an instrument needs to blend better with other instruments—in a string quartet, for example—more substantial bridges tuned to a lower frequency may be appropriate.

At the 2004 VSA-Oberlin Acoustics Workshop, researchers Fan Tao and George Bissinger worked with a team of makers headed by Gregg Alf to explore the effects of changing mass and frequency independently. They used two violins and a total of 140 different mass-frequency combinations, but the results have not yet been published. A recent paper by Erik Jansson [3] correlates the Bridge Hill with the distance between the bridge feet—and suggests to me that bridge-foot distance is an underutilized element of setup. An upcoming paper by James Woodhouse (*Acoustica*) models the effect on the Bridge Hill of independently varying mass, frequency, and foot spacing.

That said, I think that the ability to simply measure and adjust the bridge frequency is useful when setting up and adjusting instruments. For example, when a bridge is cut down in order to lower string heights, the removal of wood from the top of the bridge will raise its frequency. Trimming the waist a little will restore the frequency to its original value.

Measuring Bridge Frequency

The frequency of the bridge resonance depends very much on the measurement conditions. The feet, for example, can be clamped to a massive block, or the entire bridge can be suspended freely by a fine elastic thread, or it can be measured while strung up on the instrument. In each case, the coupling or lack of coupling with outside elements changes the resonance significantly. Which method is best? For violinmakers interested in setup and adjustment, I believe that clamping the feet to a massive block (as Jansson does) makes the most sense. It is quick and convenient, and the measurement conditions are clearly defined. When the bridge is strung up on the instrument, the bridge resonance tends to get lost among the multitude of violin body resonances in this frequency region, and so it becomes difficult to track. In free suspension, the mass of the lower portion of the bridge becomes, in my opinion, disproportionately important—and then there is the difficulty of measuring a bridge that is dangling in mid-air.

Figures 2 and 3 show the basic setup. The bridge feet are



Figure 2. The bridge is held in the jaws of a machinist's vise. A wooden wedge along one jaw complements the taper of the bridge. A wood strip glued to the wedge a few millimeters below the top face of the jaw ensures that the bridge is always clamped at the same distance from the bottom of its foot.

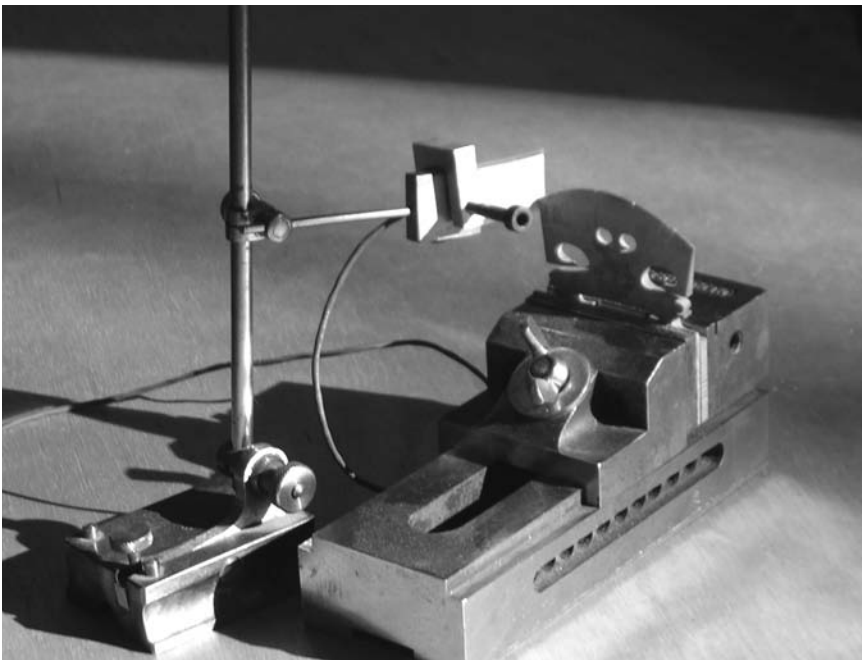


Figure 3. The piezo film transducer is clamped to a small machinist's height gauge, which allows easy adjustment of the position of the transducer.

held in the jaws of a vise; a machinist's vise works well, though almost any will do, providing its mass is much larger than that of the bridge. I attached a small wedge of maple to one jaw, the wedge being cut to an angle complementing the taper of a typical bridge. This reduces any tendency to crush the edges of the feet. A wooden stop glued to the maple wedge ensures the bridge goes down into the jaws the same amount each time, which is important for obtaining consistent measurements.

A piezoelectric film transducer (Fig. 4) lightly touches one corner of the bridge; I find that the bass corner seems to work better than the treble. The film produces an electrical signal when flexed by the bridge vibration. This signal is fed to a computer with a soundcard and the appropriate software. Figure 5 shows the resonance displayed on SpectraPLUS software.

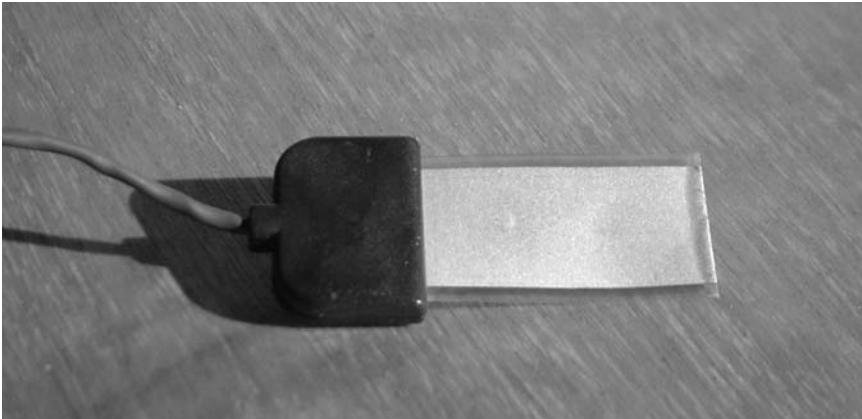


Figure 4. This piezo film transducer comes screened and with lead wires attached. It requires only the attachment of the appropriate jack in order to plug it into the computer's soundcard.

There are many other ways to pick up bridge vibration, including accelerometers, phono cartridges, laser sensors, and microphones (which work well when held very close to the edge of the bridge). The piezo film transducer has the following advantages:

- It couples only minimal mass to the bridge (coupled mass detunes the bridge, skewing the results).
- At about \$25 (or much less, if you don't mind soldering), it is relatively inexpensive.
- It produces a sufficiently strong signal to feed typical computer soundcards directly, without need for a pre-amplifier.
- It comes with leads attached and requires only an appropriate connector plug to attach it to the soundcard.

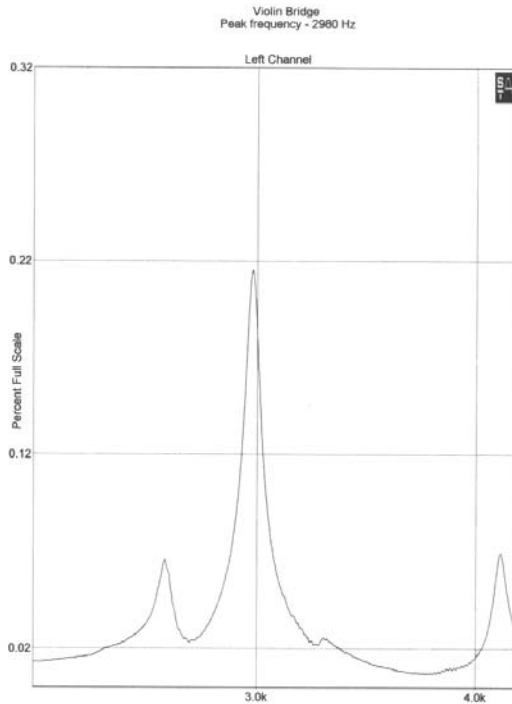


Figure 5. Resonance measurement of a violin bridge displayed on SpectraPLUS graphics.

The piezo film is clamped to a small machinist's height gauge, whose fine adjustment screw makes it easy to adjust the film's position relative to the bridge. The bridge is then "plucked" with a fingernail: Approach the bridge from the side with an upturned palm, place a fingernail into the cut-out and flick the top portion upward, thus exciting a side-to-side rocking motion of the bridge.

Hardware and Software

The sensor that I use is available at <www.msiusa.com/piezo>. It goes by the description SDT1-028K, part number 1-1000288-0. As they have a minimum order of \$100, it's worth getting together with other makers for a group order.

A less expensive (~\$1) transducer from the same manufacturer is LDTO-028K/L, part number 0-1002794-1, on the MSI website. You need to solder leads to the metal tabs that are pre-attached to the film. It is available without a minimum order from Digi-Key. The part description is MSP1006-ND in the Digi-Key catalog; the part number is 0-1002794-1. It can be ordered online

online or at the address below. Though Digi-Key has no minimum order, a \$5 fee is charged for orders under \$25.

<www.digikey.com>
Digi-Key Corporation
701 Brooks Ave. South
Thief River Falls, MN 56701-0677
1-800-344-4539

For software, programs such as Adobe Audition (www.adobe.com), SpectraPLUS (www.spectraplus.com), and WinMIs (www.winmls.com) work well for PC-based computers and SpectraFoo for Macintosh computers. Any program capable of FFT analysis should work, including ones that are downloadable for free off the web. Put the program in Spectrum mode and set the frequency range at ~2000 to 4000 Hz. To enhance the relative height of the peak, set the amplitude scaling to Linear. A clearly pronounced peak should appear when the bridge is plucked. Depending on the software, a cursor movement and/or key functions are used to identify the frequency at the highest point of the peak.

Hands-on experience with bridge tuning and this equipment is offered at the VSA-Oberlin Acoustics Workshop. For more information, contact Fan Tao at <Fan.Tao@daddario.com>.

ACKNOWLEDGMENTS

Many thanks go to Fan Tao for his help in preparing this article.

REFERENCES

- [1] E.V. Jansson, L. Fryden, and G. Mattson, On tuning of the violin bridge, *Catgut Acoustical Soc. J.*, Vol. 1, No. 6 (Series II), pp. 11-15 (Nov. 1990).
- [2] E.V. Jansson and B.K. Niewczyk, On the acoustics of the violin bridge or body hill, *Catgut Acoustical Soc. J.*, Vol. 3, No. 7 (Series II), pp. 23-27 (May 1999).
- [3] E.V. Jansson, Violin frequency response—bridge mobility and bridge feet distance, *Appl. Acoustics*, Vol. 65, pp. 1197-1205 (Dec. 2004).

Also of interest:

O.E. Rodgers and T.R. Masino, The effect of wood removal on bridge frequencies, *Catgut Acoustical Soc. J.*, Vol. 1, No. 6 (Series II), pp. 6-10 (Nov. 1990)