Comparison of a Bridge Foot Vibrations using Natural and Artificial Types of Violin Excitation

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Abstract
To produce a violin sound when measuring its acoustic properties the Dünnwald's transducer is often used to excite the bridge vibration instead of a natural form (string vibrations are evoked by a bow movement). The vibrated transducer's wire is applied on a bridge side near the string E. Bridge foot vibration was registered by means of a double beam laser vibrometer by both natural and artificial forms of violin excitation. Bridge foot vibration in each excitation type differ; it is unclear whether this is due to the string and transducer act on different positions on the bridge or the influence of the transducer wire's mass on the instrument, or both.

Introduction

In some situations, artificial excitors are used to detect acoustic properties of musical instrument. Such substitutions by musicians allow a long-term, stable and repeatable elicitation of investigated properties. This type of instrument excitation has some limitations. Usually it is not possible to simulate several playing techniques using only one type of artificial excitor, and instrument properties may be modified through this excitor.

Design of an applicable excitor and its use require to minimising the excitor's influence on the instrument. In the case of measuring the violin frequency response transfer function (FRTF) the comparison of different artificial excitor types was made (Janson & all, 1986). Here Dünnwald's transducer (Dünnwald, 1984) was judged as "not influencing resonance frequencies, having sufficient reproducibility, not damaging the instrument in any way".

An example of the use of the Dünnwald's transducer is the evaluation of the objective sound quality of the violin (Dünnwald, 1990). For that purpose Dünnwald calculated single tone harmonic component magnitudes through the subtraction of the transducer response and of the spectrum of the bowed string excitation force from measured FRTF. However, as we found from our own experiment, the tone spectra calculated this way differs from that played by a musician, even when recorded in the same instrument - microphone position. The experience was similar when we compared directivity index levels measured by means of natural tones played by a musician (Otcenasek, Syrovy, 1999) and by using of Dünnwald's transducer.

Reasons for this difference may include the following:
1) the excitor may influence the instrument properties,
2) since the excitation powers on the bridge have unequal positions depending on the used type of excitation (string or transducer) the excitation force may be divided into two bridge foot forces by different means.

Foot vibrations due to bridge foot forces can be visualised by using of a laser vibrometer and both types of violin excitation can then be compared.

Method

The vibrations of both feet were observed simultaneously with two beams of the laser vibrometer for both compared types of the violin excitation:
1) **naturally** - with a bow by the musician (marked by N in Figures),
2) **artificially** by Dünnwald's transducer (marked by A in Figures).
The violinist played a G3 tone on a free string, in 1.5 s duration, *Col legno.*

Mezzoforte dynamic and the 20-mm bow position distance from the bridge were maintained. During the process of the laser beams setting the free string frequency fell slightly to f_0=187 Hz.

Dűnnwald's transducer was powered by the amplified signal of the sinus generator. Only frequencies of the first 30-ty harmonics of G3 tone were set.

A Dual-beam fiber optic vibrometer (POLYTEC OFV-518, OFV-2802i) was used. Time envelopes of the foot vibration signals were digitalised. The stationary part of the most stable tone from several repeated tones was used for comparison.

The bridge foot surface was not manipulated to improve its reflection, so as not to damage the instrument or influence it by mass from the reflecting tape. Thus the reflected beam had a lower intensity (3 levels out of possible 20 available on the indicator) and optical surface roughness was more visible as noise in the vibrometer signal (see Figure 1).
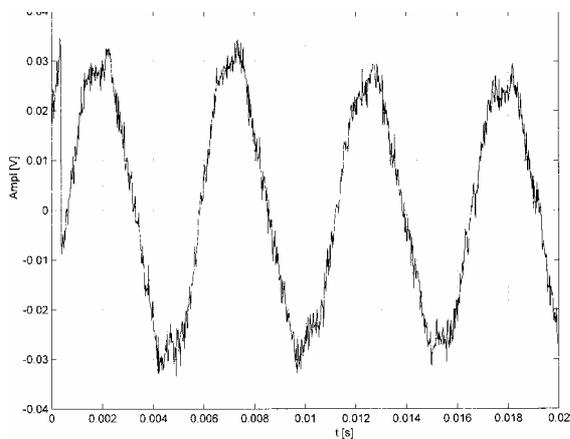

Figure 1 Foot signal with speckle noise

"**Speckle noise**" or amplitude modulations appear in a signal when coherent reflected beams are dephased from unlike distances of rough surface points. Some reflected wavelets of the beam interfere constructively and others destructively, in chaotically changing quantity as the foot surface points move (Rothberg 2002).

The bank of bandpass filters (MATLAB; Butterworth; n-th harmonic frequency $f_n = n*f_0$, n = 1, ..., 30; stopband attenuation $R_s = 50$ [dB]; cutoff frequencies $W_{n1} = f_{n-1}$ [Hz], $W_{n2} = f_{n+1}$ [Hz]; passband corner frequencies $W_{p1} = f_n - 7$ [Hz], $W_{p2} = f_n + 7$ [Hz]) was used in both cases to remove harmonics from the played tone and to minimise speckle noise.

To visualise and compare **artificial** (A - **dotted line** in Figures) and **normal** (N - **solid line** in Figures) types of bridge foot vibrations, both artificial foot signals were shifted in conjunction in time and changed in amplitude scale so that in Figures both normal and artificial **left foot** signals had the same course (**thin line** in Figures). Therefore amplitude and phase coincidences or differences on **right foot** courses (**strong line** in Figures) became visible.

Results and discussion

Selected examples of coincidences of right foot courses and also of its differences in amplitude and phase acquired with both methods (natural musician-bow-string excitation and artificial Dűnnwald's transducer excitation) are presented in Figures. Both foot courses acquired with artificial excitation were shifted in time, so that courses of artificial and natural left foot signals have the same phase; furthermore their Y-axes scale was changed so that the courses of left foot signal have the same amplitude.

Amplitude and phase coincidences were found on frequencies: 187, 375, 562, 1685, 2621, 2808, 3557, 3931 Hz (see **Figure 2 for** an example of amplitude and phase coincidence). Phase coincidence and amplitude differences were found on frequencies: 749, 1310, 1497, 2059, 2246, 2434, 3744, 5616 Hz (see **Figure 3 and 4** for an example of amplitude difference and phase coincidence). Large amplitude and phase differences appeared on frequencies: 1872, 4305, 4493, 4680, 4867, 5054, 5242, 5429 Hz (see **Figure 5, 6 and 7** for an
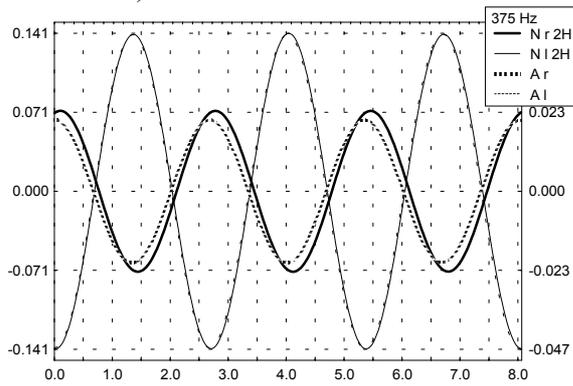
example of amplitude and phase differences).

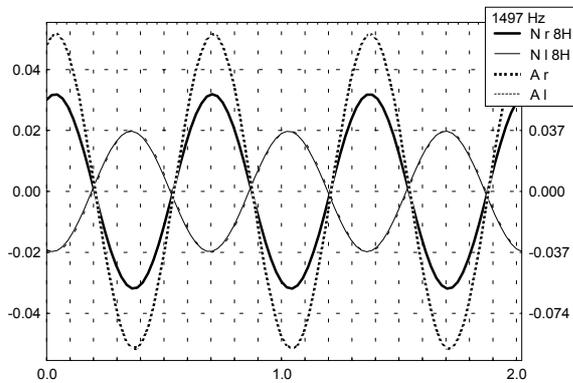**Figure 2** An example of amplitude and phase coincidence.

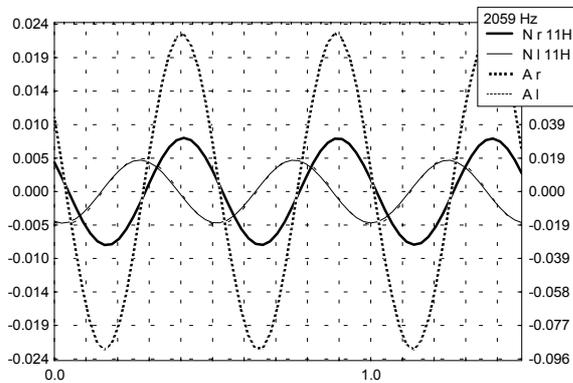**Figure 3** An example of amplitude difference and phase coincidence.

Figure 4 Another example of amplitude difference and phase coincidence.
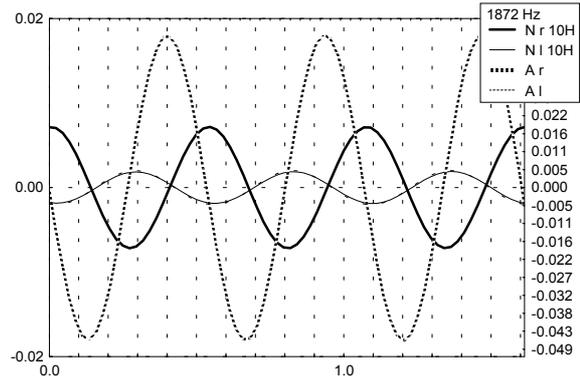

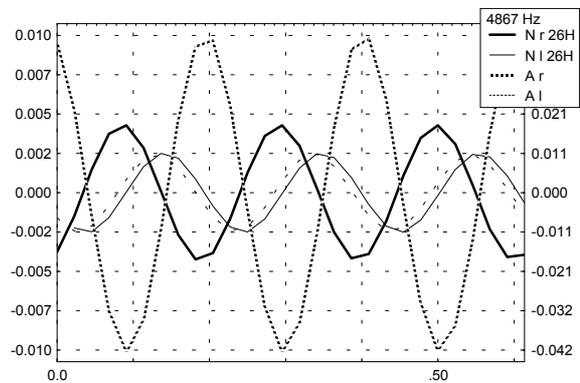**Figure 5** An example of amplitude and phase differences

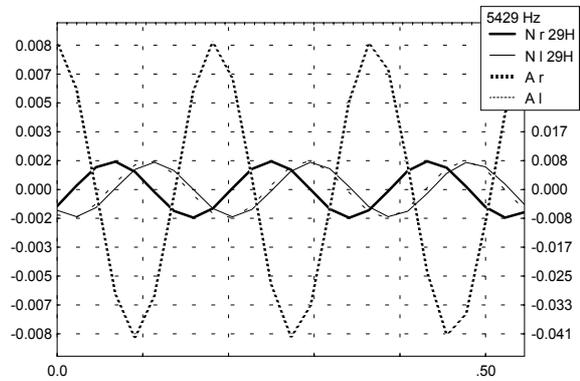**Figure 6** Other example of amplitude and phase differences

Figure 7 Another example of amplitude and phase differences

Based on the above findings, it is possible to conclude that the compared natural and artificial types of violin excitation are not identical and that they produce, especially above 4 kHz, different courses of foot vibration.

References

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