Input admittance measurements and their relation to the sound characteristics of violins and violas

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Abstract
Input admittance measurements were made on thirty instruments of the Orpheon Foundation instrument collection using the new, portable violin instrument measurement system VIAS.
This kind of measurement requires no anechoic chamber and does not induce any damage, making it suitable for analysis of historical instruments at the place where they are stored.
Investigations have been made to verify the significance of input admittance curves and pictorial representations derived from them through VIAS with respect to sound quality of stringed instruments. Recordings of the instruments played by violinists in normal and echoic rooms were analyzed and compared with predictions derived from VIAS results. Listening tests have been made to verify the correlation. It has been found that correct predictions about the sound quality of a violin can be made based on VIAS data, especially if complementary measurements at different positions on the bridge are made, and if air resonances which are not adequately represented in such curves are taken into account.

INTRODUCTION

VIAS is an opto-acoustical admittance measurement system for stringed instruments developed at the Institut fuer Wiener Klangstil.[1] The system consists of a holding structure, the adjustable measuring head, a laser controller and special software.

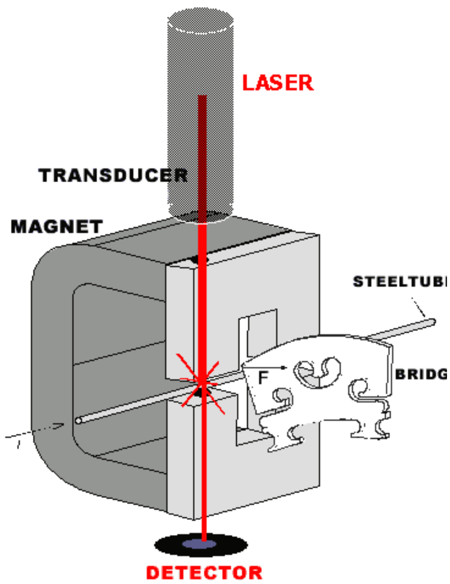

fig. 1 schematic drawing of VIAS

The illustration shows the basic principle of VIAS: an input signal, most commonly a sine wave sweep from 40Hz to 10kHz, drives a steel tube, or needle, between the poles of a magnet. The needle contacts the treble side of the bridge on the stringed instrument. The motion of the bridge is recorded by the light detector, which measures the amount of laser light the needle blocks as it moves with the violin. This information results in a curve that represents the input admittance. Since a reliable calibration for VIAS has yet to be found, the curve will be referred to as a *resonance profile*. Measurements on some of the over 100 instruments of the Vázquez collection were made to deliver a large amount of data to compare VIAS data with the actual radiated sound of the played instruments.
Nineteen violins and nine violas were measured with two different VIAS systems, which varied in size and type of holding structure. The instrument hangs in the larger structure, whereas it is clamped at the pegbox in rubber with the smaller structure. Additionally, recordings to document timbre and resonance behavior were made including nine violins played by Prof. Vázquez [2]four violins in an echo room.

RESONANCE PROFILES

What can be read directly from VIAS curves?

1. The distribution of admittances shows what type of instrument was measured. (See fig.2)
2. The timbre, for example “nasal” or “harsh” can also be approximately predicted.
3. The connection between single modes and body size can be seen: larger instruments have markedly lower main body resonances. Among the viola curves pictured (See fig.4and 5), a peak distribution spanning over 150 Hz among instruments differing up to 42 mm in body length can be observed.
4. The type of holding structure influences curves under 200 Hz (below the playing range of the violin).

A comparison of recordings of the nine played instruments with synthetic sounds derived from VIAS curves yielded no significant similarities in listening tests. Also, analysis of partials from the recordings sometimes showed the opposite result of the intensity displays of VIAS.

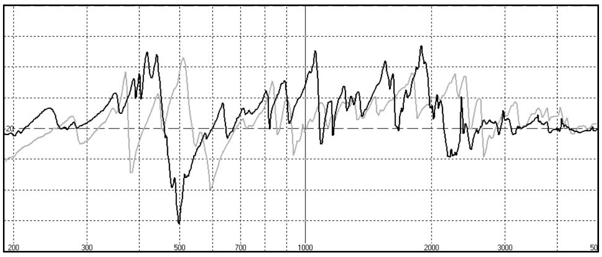

fig. 2 Resonance profiles of a violin (gray line) and a viola (black line)

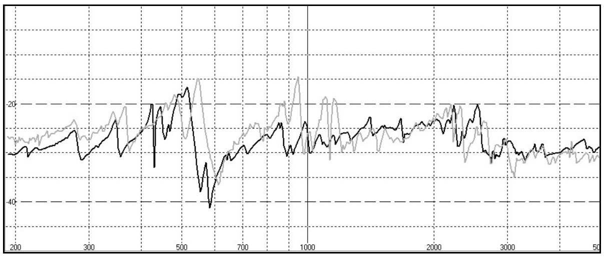

fig. 3 Comparison of a violin with a nasal timbre (gray line) and a violin with warm and full timbre

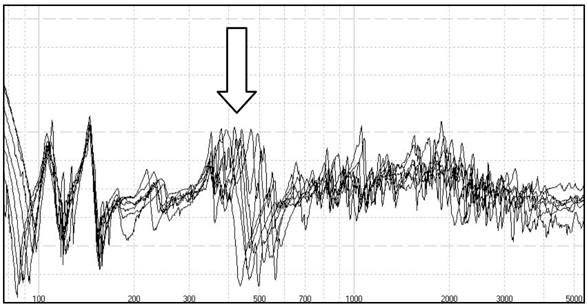

fig. 4 Resonance profile of nine violas. The very similar peaks below 200 Hz are caused by the holding structure. The peaks of the main body resonances are quite different (320 –500Hz) and are linked to the instruments size: the body length reached from 420 to 378 mm.

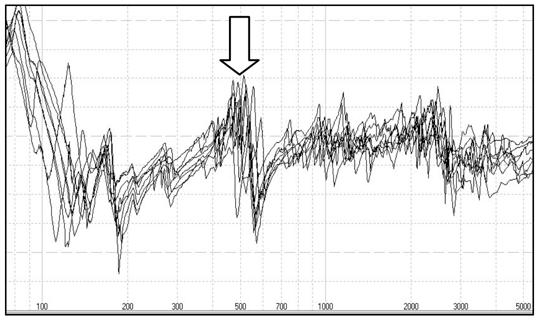

fig. 5 VIAS curves of nine violins. The main body resonances are located in a smaller range (450-540 Hz)

TRANSFER FUNCTION

In order to better understand the input admittance and transfer function, further recordings of four violins played by a violinist were made in an echo chamber. Recordings of the radiated sound of the instruments were also made during VIAS measurements. The room[1] has a volume of 183m and an inner surface of 205.6 m2, with an average delay of approximately 5 seconds.

VIAS software was then expanded to accommodate the recorded Wav audio files, from which new curves can be derived. This enabled a direct comparison of the resonance profile and the transfer function.

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The following results were found:

1. The frequencies from G3 to C4 (196 Hz to 277 Hz) are exaggerated by VIAS. This is possibly due to the fact that the surface of the instrument is too small to radiate these frequencies.
2. The peaks near 280 Hz and 520 Hz seem to be shown in VIAS resonance profiles lower than they actually sound. There is a discrepancy between friction losses in air and body modes, which are therefor measured differently by the admittance system.
3. D5 and D#5 (587- 622 Hz, and the second partial of D4, etc.) are shown in resonance profiles to be particularly weak, while the transfer function does not show this tendency.
4. The second partial of F5 (ca. 700 Hz) is shown weaker in the resonance profile. This is probably due to vertical bridge motion not measurable by VIAS in the horizontal bridge position.

During these experiments, the hollow needle of the VIAS measuring head was replaced by a protruding plate of copper-coated epoxy, enabling experimentation and measurements in the vertical direction.
There was in fact a vertical motion at 700 Hz showing that VIAS underrates the admittance for this frequency.(fig.8)
The identification of idle power and power that results in radiated sound should in future be possible through use of the phase information of the measurement (real and imaginary parts). At present, other factors influence phase information, such as the electronics of the system and the computer soundcard, and this influence will only be eliminated with an accurate calibration. In future, measurements from the treble, bass and vertical directions will be combined on one curve to provide a more accurate resonance profile.

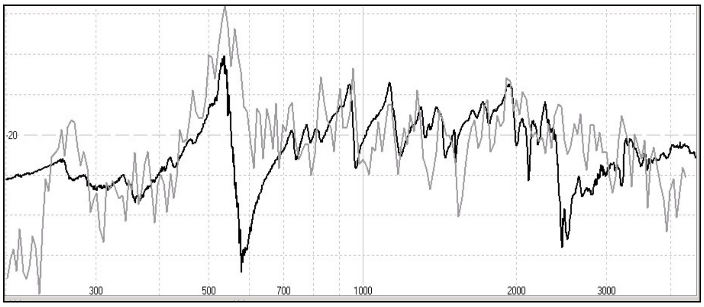

fig. 6 Regular VIAS curve (black) and the signal of the radiated VIAS sound of the same violin measured at the same time.

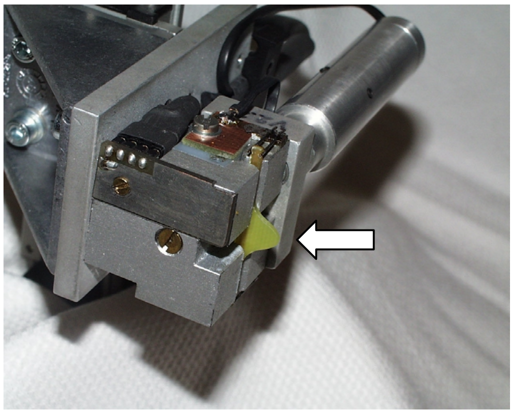

fig. 7 New measurement head with epoxy plate protrusion

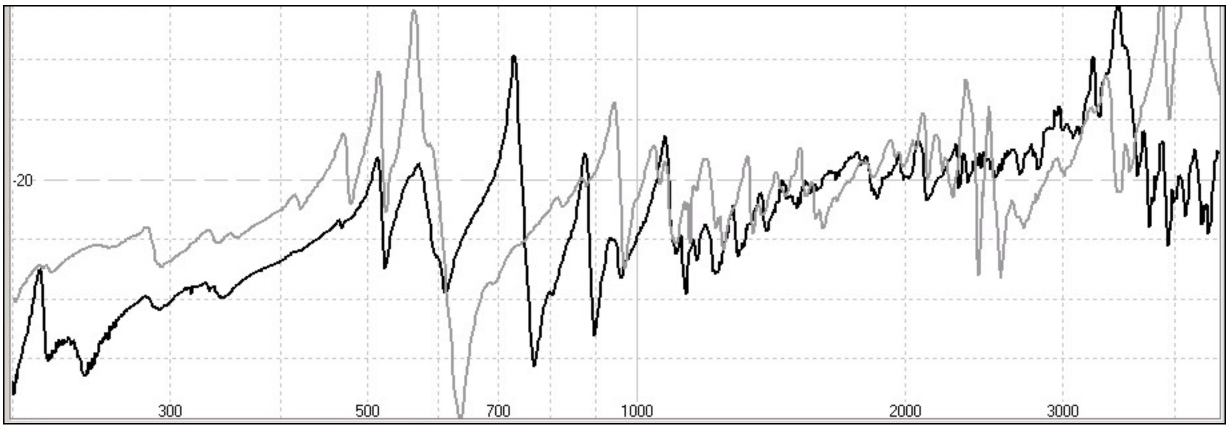

fig. 8 VIAS curves of the same violin measured parallel (gray line) and vertical to the string plane (black line) Note the high peak at 720 Hz which is not visible at the other graph.

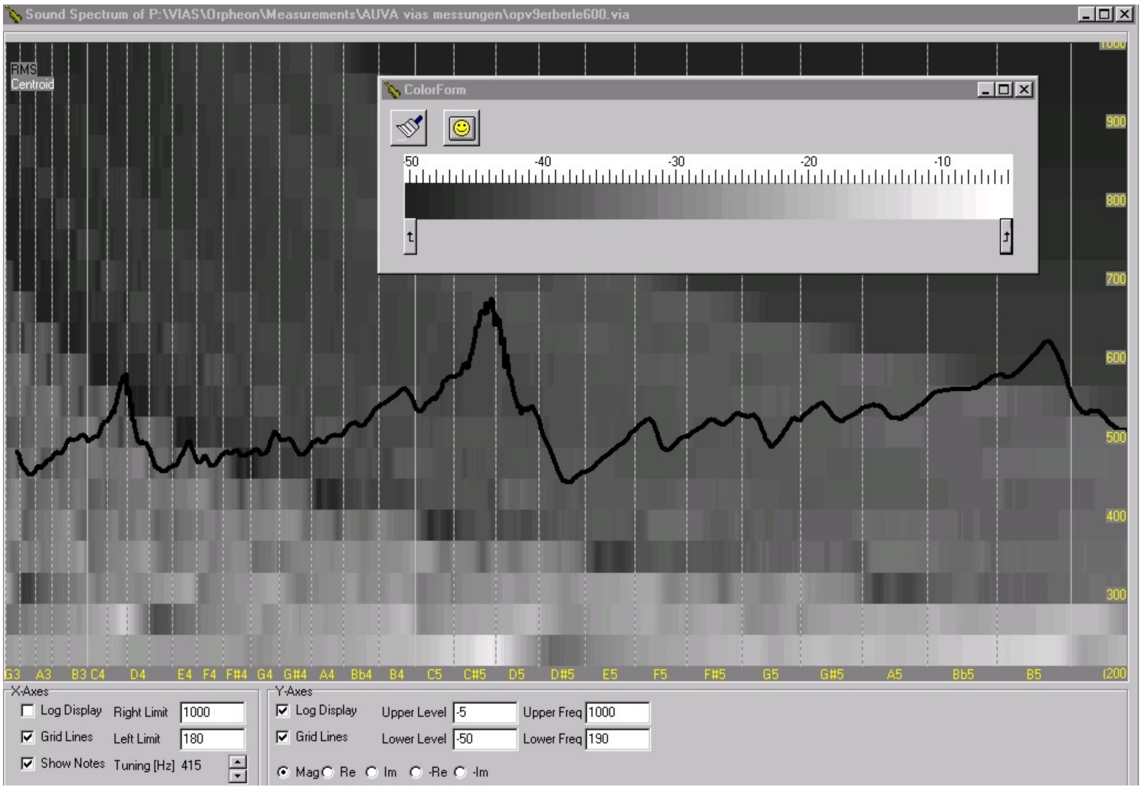

fig. 9 The Soundgraph Display shows for all playable notes (frequencies) the theoretical calculated distribution of the overtones (harmonics) which form the sound color of the instrument. It is assumed that the vibration of the bowed string can be approximated by a saw-tooth-signal. This source signal gets then modulated by the measured resonance profile (= admittance curve) of the actual loaded instrument. The black graph is the RMS .

SUMMARY

VIAS makes acquiring input admittance data of stringed instruments simpler and easier. The resulting resonance profiles can be used for documentation, restoration and making new instruments. Corrections to these resonance profiles are required in certain areas: G3-C4 are shown more strongly on the resonance profile than heard on a played violin on account of idle power, while the A0 and A1 air resonances are shown weaker on account of friction losses. Vertical motions of the bridge should also be taken into account.

REFERENCES

[1] Kausel, Wilfried: Opto-akustische Eingangsadmittanzmessung an Streichinstrumenten. Internet URL: http:// iwk.mdw.ac.at/deutsch/Forschung/VIAS, 1999

[2] Orpheon Foundation: Internet URL: http:// www.orpheon.org ,2000