PREDICTON OF VIOLIN RADIATION PROPERTIES IN THE 200-700 Hz RANGE

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Abstract

The radiation at low frequencies is especially difficult to measure without a special measurement room, an anechoic chamber. A fundamental relation suggests possibilities to indirectly measure the radiation. For a vibrating enclosure the sound radiated is proportional to the sound pressure generated inside the volume multiplied by the frequency squared. The sound pressure in the cavity can be measured simply with a small microphone or with a probe-microphone (technique developed for measuring loudspeaker cabinets by S Granqvist and J Liljencrants). The microphone is positioned at a nodal line of the first airmode A1. Then the A1 influence should be removed and the measurement range may cover the main low-frequency resonances of the violin, 200-700 Hz. Measurements are made on two violins of fair quality, of sound pressure inside the cavity and of radiated sound in an anechoic chamber, to evaluate the possibilities of the method. The measurements of radiated sound showed that the violin is an omni-directional sound source in the 200-700 Hz range. With the microphone inside the cavity in the bridge plane a good signal is obtained with little influence of the room but the A1-influence is not safely removed. The resonant frequencies are accurately predicted but the radiation levels less well. The method is further tested on three violins of soloist quality (Stradivarius, Guadagnini and Gagliano). Again the measurements indicated that the A1 resonance may demand individual fine adjustments of microphone position for some violins and that there may be an additional parameter to be included in the prediction of radiated sound levels. The experiments show that measured sound pressure response inside the violin cavity in the plane of the violin bridge predicts low frequency properties of radiated sound as well as the common bridge mobility measurements at KTH. The method with measuring sound pressure inside the cavity is simpler to implement though – pulse excitation with a pendulum and FFT-analysis of the microphone signal with a personal computer (PC).

INTRODUCTION

The sound radiation of a violin should, in the low-frequency range, mainly come from volume changes of the violin body, i.e. the body regarded as a zero order radiator resulting in spherical radiation. Higher vibration modes should be rather inefficient sound radiators in the low frequency range. The radiation pressure p_r for spherical radiation of a small source at a large distance r obeys the equation below where Q is the source strength, ω the angular frequency and ρ air density (ref 1 p 164 eq 7.36)

$$p_r = \frac{j\omega\rho}{4\pi r} Q$$

The sound pressure p_i generated inside an air volume with vibrating walls obeys the following equation where c equals the velocity of sound in air (ref 1 p 187 eq 8.2)

$$p_i = \frac{\rho c^2}{V} \frac{Q}{j\omega}$$

and thus the relation far field sound pressure to internal sound pressure obeys the equation

$$\frac{p_r}{p_i} = \frac{(j\omega)^2 V}{4\pi r c^2}$$

Inside the air cavity of the violin body at about 460 Hz, a resonance A1 can be found, see figure 1. This resonance has a pressure node close to the plane of the violin bridge. If a measurement (pressure) microphone is placed in the bridge plane, the influence of the A1 resonance should be small on the measured properties of the air cavity. Thus the last equation should predict relation between sound pressure inside the violin body and the sound pressure in the far field. The demands are that the measures of the violin body should be small compared to the wavelength of the sound (uniform sound pressure in the cavity). As this demand is not quite true, the validity of the relation must be experimentally tried. If the relation is valid it opens a new indirect simple way to measure low-frequency radiation of a violin.

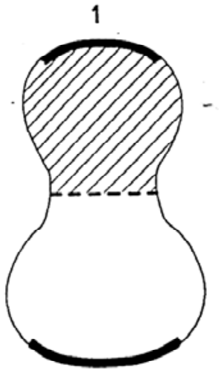

Figure 1. Sound pressure distribution at air mode A1 (dashed line marks nodal line, broad lines pressure maxima, and shaded and blank areas phase relations)

MEASUREMENTS ON TWO VIOLINS OF FAIR QUALITY

The sound radiation curves show that the peak levels of A0, P1 and P2 are the same within 1 dB, for each of the two violins, i.e. the violins are omni-directional radiators in this frequency range, see figure 2. The peak levels for the A0, the P1 and the P2 of the Bernardel violin are at 0, 4, and 6 dB respectively. The P2 peak is slightly higher than the P1. For the Glass violin the A0, the P1 and the P2 peaks are at 1, 6, 0 dB, respectively. The P2 peak is now lower than the P1.

In the sound pressure measurements in the cavity of the Bernardel violin we find the P1, and the P2 peaks at -4, and +1 dB, respectively, see figure 3 (the sharp peaks and dips just below 500 Hz are experimental accident). The accuracy of measurements limits the analysis to a qualitative one. The P1 and P2 peaks are at about twice the frequency of the A0, i.e. an addition of approximately 12 dB to that of the A0. This agrees reasonably well with the measurements. In finer detail we find that the P2 peak is predicted slightly higher than the P1 and still higher than in the radiation response. Little influence of the A1 mode at 460 Hz is found. In the Glass violin we find for the peaks P1 and P2 at –1, and 0 dB, respectively. The P2 is slightly lower than P1 but not much lower as in the radiation response. The A1 mode at 460 Hz is influencing the result in this case though, indicating that the microphone is off the A1 nodal-line.

Thus the prediction of the radiated sound level is somewhat doubtful even qualitatively. The A0-peaks are at similar levels for the Bernardel and the Glass violins both in the cavity and the radiation measurements which is as it should be. But the P1 and P2 radiation peak levels are not well predicted. The P2 is higher than P1 in the cavity measurements for both violins but much lower in the radiated sound for the Glass violin.

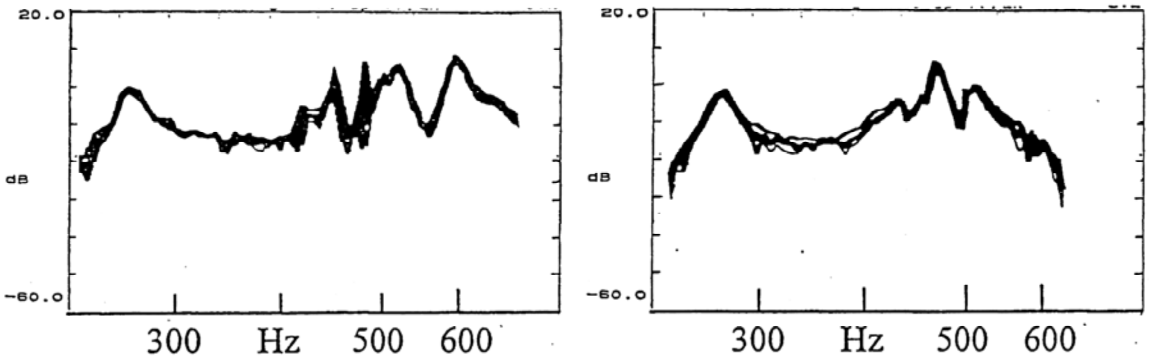

Figure 2. Sound radiation a) of the Bernardel violin and b)of the Glass violin (in each diagram the radiation in four perpendicular directions in the bridge plane are included in the thick line)

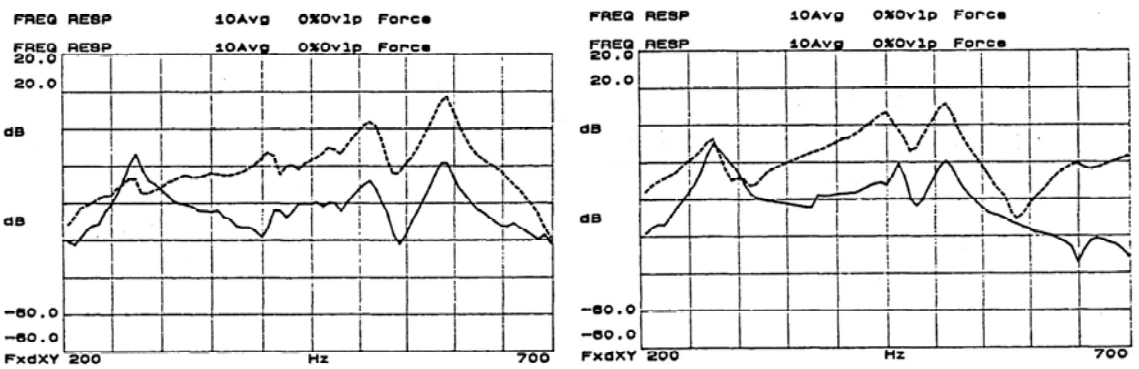

Figure 3. Measured sound pressure in the air volume (continuous line) and bridge mobility (dashed line)of violin a)L. Bernardel and b) Glass

The bridge mobility measurements predicts the peak levels of the cavity measurements reasonably well (in two cases of three), see figure 3.

MEASUREMENTS ON THREE VIOLINS OF SOLOIST QUALITY

A microphone with a plastic tube-sond can be used without danger on soloist violins (< ±1 dB deviations relative to microphone)! Sound pressure measured by this sond in side the cavities in three violins of soloist quality are shown in figure 4

In the bridge mobility and air cavity measurements of the three soloist violins the following result is found, see figure 4. The A0 peak is at approx. the same levels and the P1 and P2 peaks at 20 dB higher levels in the bridge mobility responses than the air cavity responses. The A1 peak is completely removed for the Gagliano violin, weak but visible for the Guadagnini but not removed from the Stradivarius violin. The results indicate a different non-uniform distribution of sound pressure in the violin cavities and an additional parameter not accounted for.

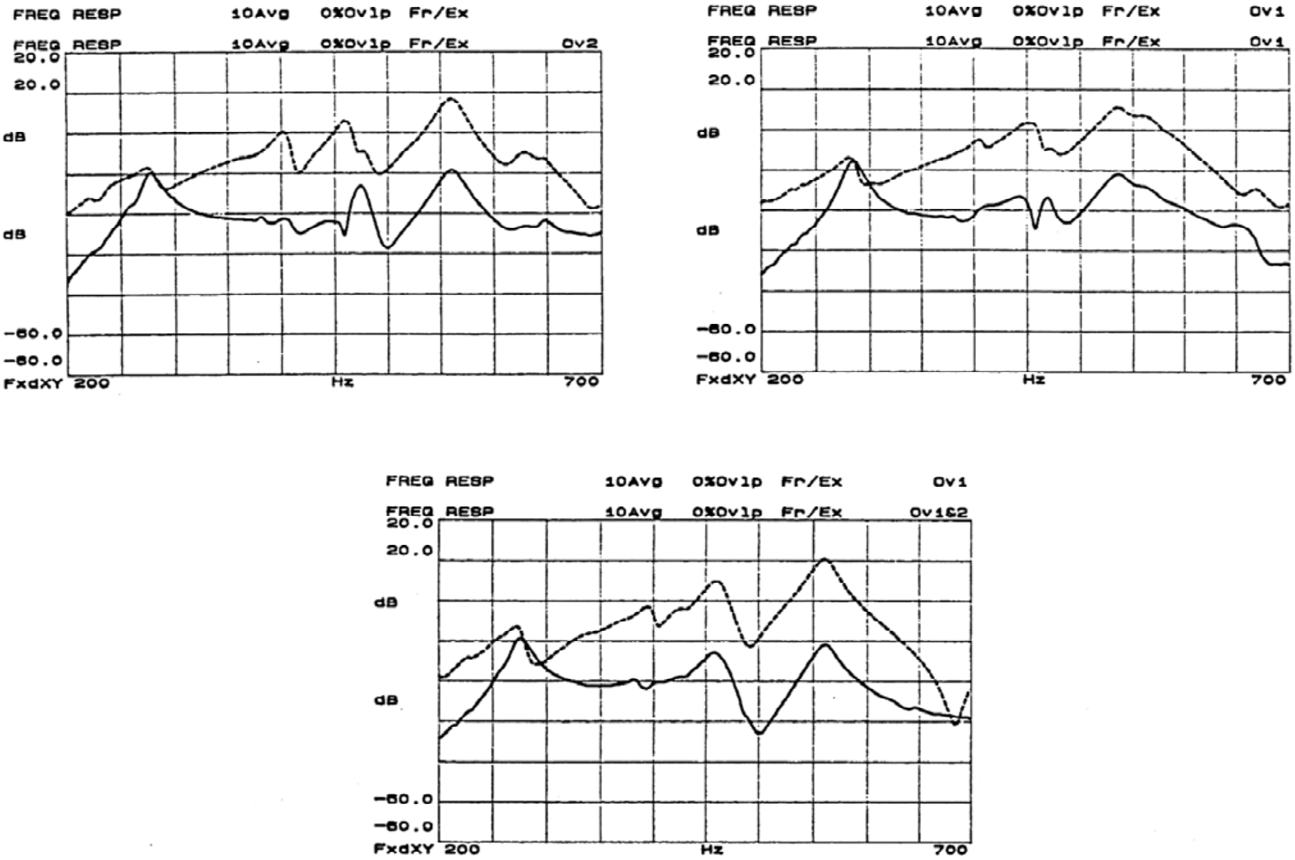

Figure 4. Sound pressure in the air volume (continuous line) and bridge mobility (dashed line) violin a)Stradivarius, b) Guadagnini, and c) N Gagliano

CONCLUSIONS

This study of a simple method to predict radiated sound from a violin indicates that the suggested method can be useful. The sound radiation is omni-directional say 250-600 Hz. The frequencies of the A0, P1 and P2 peaks are well predicted by measuring sound pressure in the cavity. The influence of the A1-cavity mode can be removed extending the range to 700 Hz. The radiation levels seem to be predicted about equally well by air cavity and bridge mobility but unfortunately not too well. More work is needed to increase the understanding the reasons for deviations. Although not clearly working too well for predicting radiation ,the sound pressure inside the violin cavity seems promising for future use. A great advantage is that it is simple to apply and use. The side of theviolin bridge is excited by a pendulum and the air cavity response is presented in the traditional frequency response means of a sound card and a FFT-program in a personal computer (PC).

REFERENCES

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