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VIBRATION CHARACTERISTICS OF FREE VIOLIN PLATES AND THEIR RELATION TO TAP TONES DATA

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Frequency responses of freely suspended violin plates were measured using various kinds of plate driving and microphone location. Spectral densities of tap tones were also measured, using different points of holding, tapping and listening. The data are discussed with reference to those obtained by HUTCHINS *et al.* [1, 2, 3].

1. Introduction

Over thirty years ago, HUTCHINS, HOPPING and SAUNDERS [1] developed the concept of the „plate tone" for examination of unassembled violin plates. For this test a very light coil was attached to the centre of the freely suspended violin plate. The suitably prepared magnet pole was inserted into the coil to which a variable frequency and constant amplitude voltage was delivered. The response of the plate was picked up by a ceramic microphone. The usefulness of this test is not in question as it has been successfully used in the construction of a substantial number of instruments.

Later these authors (HUTCHINS, HOPPING and SAUNDERS [12]) gave a description of new testing equipment using a moving armature type driver and a microphone at 45 cm distance from the plate surface. The latter point seems to be reasonably important since it shows that the microphone picks up the sound energy from this part of the field where strong interference due to modal division and finite plate dimensions occurs. Also, it explains why the low frequency emission is practically cut-off, resulting in frequency response record showing: „the lowest strong resonance of the plate observed by this method", as high as 300 to 400 Hz (HUTCHINS, STETSON and TAYLOR [3]. Thus, low frequency information is not represented in these recordes.

In the previously mentioned paper, HUTCHINS *et al.* [2] state that, „before one taps a violin plate it is necessary to settle where the plate is to be held and where tapped". In this statement, which is of course very true, one additional point seems to be missing. Namely: which exact point the listener's ear should be placed? The situation analogous to the one during the electroacustic testing described by Hutchins, Hopping and Saunders should occur only by keeping the plate 45 cm from the ear. However, to the authors' knowledge, tapping by violin makers is almost invariably done while keeping the plate rather close to the ear. In this situation, various tones can be heard depending on the exact place of listening, even if holding and tapping is done always the same way. This is due to the fact that tapping the plate, i.e. application of the mechanical pulse signal, produces a number of vibration modes and corresponding tones are radiated from various places of the plate depending on the distribution of modal lines.

In pilot experiments made prior to the research described in the present report, a group of eight expres, with very substantial experience in the experiments pertaining to pitch perception, performed the tapping on the same violin top plate. The plate was taken from the unassembled superior quality violin made late in the 18-th century by an unrecognized Italian violin maker. The plate had integral bass bar curved from the same piece of wood. Listeners were holding the plate at a given point and determined pitch intervals between tones heard from the strictly determined two points keeping the plate very close to the ear. The pitch interval thus determined was close to fourth in median value, with intersubject differences amounting to one semitone. The above observation shows that configuration of the near field naturally explored by violin makers in traditional tap-tone tests must be taken into account while choosing the place of listening. The main purpose of the present report is to show the physical differences in the signals obtained by driving the single top plate in various ways and by picking up the sound emitted by the plate from various points in the field. Some earlier data, obtained from sine driving, using Hutchins' method, and from the transducer with motional feedback driving, are also discussed, showing significant differences. The judgements of tap-tone pitch obtained from a group of six expert listeners are included.

2. The equipment and methods

A. Sine driving

In some earlier experiments with sine driving of freely suspended or clamped plates, a simple electrodynamic transducer with motional feedbeck (Jaroszewski [4]) was used. With this transducer, driving with constant velocity or constant acceleration was obtained using a BK 1024 generator and compressor at 1000 dB/s with suitable 6 dB/oct filters. To compare the results with those obtained by Hutchins *et al.*, the coil driving of freely suspended plates (on rubber threads) was also used, possibly similar to that described in the Hutchins report [1]. The sound was picked-up using a condenser microphone located at various points of the plate 1 cm from its surface. In some tests this spacing was enlarged to 32 cm. The microphone output was amplified and fed to a BK 2305 level recorder. The measurements were conducted in a small acoustically treated room (reverberation time less than 0.5 sec).

B. Tap tones

The tap tones were picked-up with a BK 4145 1" condenser microphone located at specified points 1 cm from the plate surface and recorded on magnetic tape using a NAGRA portable tape recorder. Loops with the recorded tap tones were then analyzed using a BK 2020 slave heterodyne analyzer system at constant 3.16 Hz bandwidth. Integration constant of the level recorder was set at 500 ms to eliminate amplitude variations present in the original tap tone records. In listening to the tap tones performed by the experts, the plates were held so that the appropriate points were as close to the ear as possible. The tapping and listening was done in a way exactly following the one used by professional violin makers. The distance between the plate and the ear was about 10 cm. The tapping was performed using a knuckle of the second joint of the bent right hand forefinger. The plate was held and tapped by the same person. In all experiments the plates were held, driven or tapped and the sounds picked up at the three points V_1, H_1 and H_2 after HUTCHINS *et al.* [2], Fig. 1. All measurements and listenings were performed in the same, acoustically-treated room.

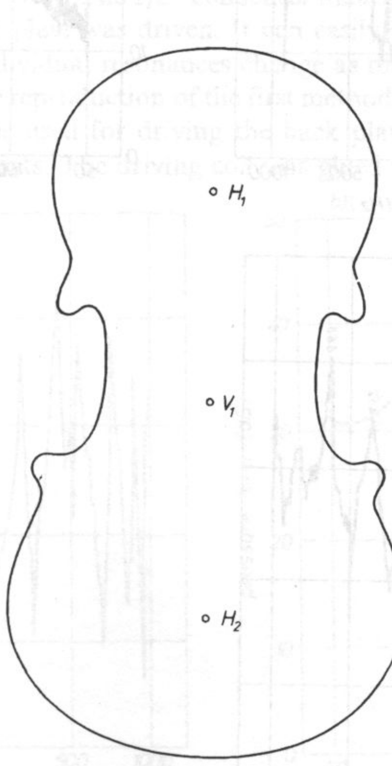
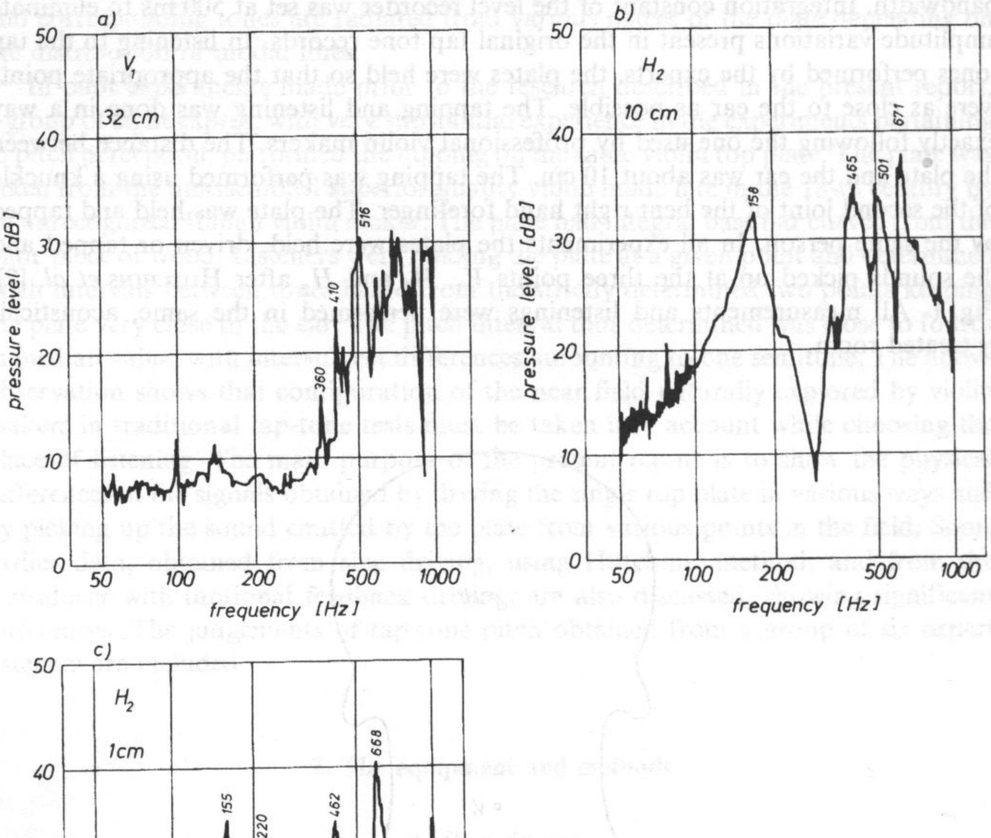


Fig. 1. Three points V_1, H_1, H_2 where the plates were held, driven or tapped and the sound picked-up (after HUTCHINS *et. al.* 1960).

3. The results

A. Sine driving

The results obtained with sine driving, both using an electrodynamic transducer with motional feedback, and the first method of those used by HUTCHINS *et al.*, (i.e.



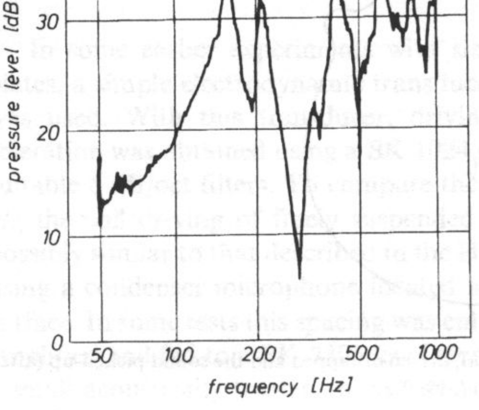


Fig. 2. Response of the sine driven tap plate dependent on plate — microphone spacing and pick-up point. Constant velocity at dreving V_1.

with speaker coil glued to the center /V_1/ of plates), are presented in Figs 2 to 5. Fig. 2 presents responses of the top plate of the superior quality violin (Italian make, late 18-century).

The plate was driven at V_1 with constant velocity and the sound emitted picked-up using a BK 4131 1" microphone at normal to V_1 and 32 cm from the plate surface. This response is similar to those that appear in the publications of Hutchins *et. al.*, in that the low frequency components are cut-off. For the case presented in Fig. 2 a, the lowest strong resonance should read as 360 Hz or perhaps even 410 Hz. Lower resonances were also not observed at normals to H_1 and H_2 of the same plate when the microphone was 32 cm from the plate surface. Also they were absent with different types of sine driving i.e. constant amplitude or acceleration. However, when the microphone is closer to the surface, the same plate driven also at constant velocity shows one or two well pronounced resonances lower that 360 Hz, and these are represented in Fig. 2 b and Fig. 2 c. How rapidly the field changes near the surface of the plate may be seen from the comparison of records obtained at two plate — microphone spacings, 1 cm and 10 cm (i.e. Fig. 2 b and Fig. 2 c respectively).

The effect of type of driving (i.e. constant velocity, constant acceleration) is shown in Figs. 3 a and 3b respectively. The 1/2" condenser microphone BK 4134 was located 1 cm from V_1 where the plate was driven. It can easily be seen that the amplitude relations between the individual resonances change as much as by 10 db.

The possibly accurate reproduction of the first method of plate driving introduced by Hutchins *et al.*[1] was used for driving the back plate of another violin, a low priced student's instruments. The driving coil was glued at V_1. The responses taken

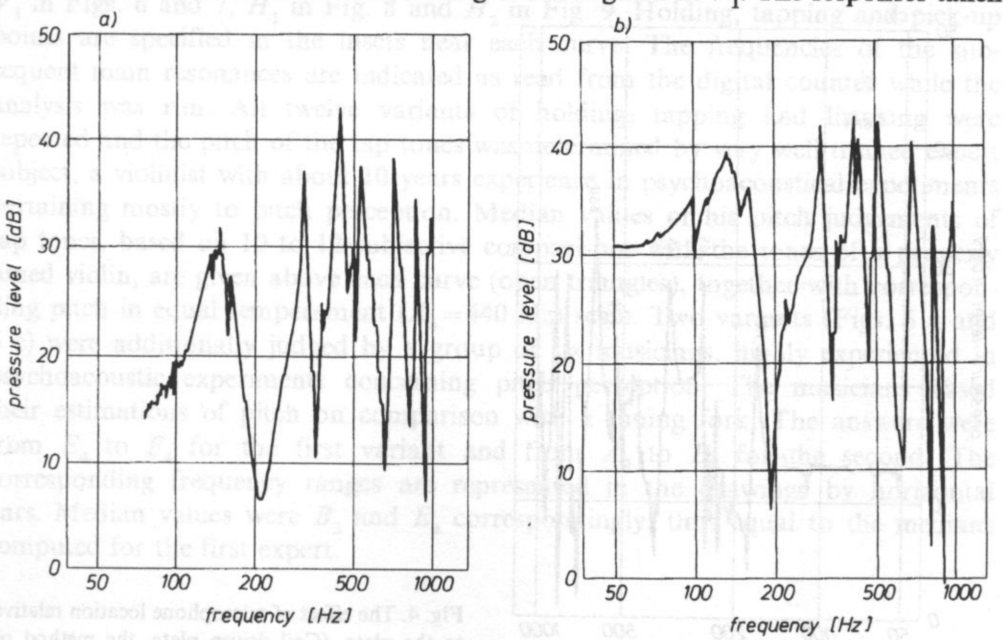
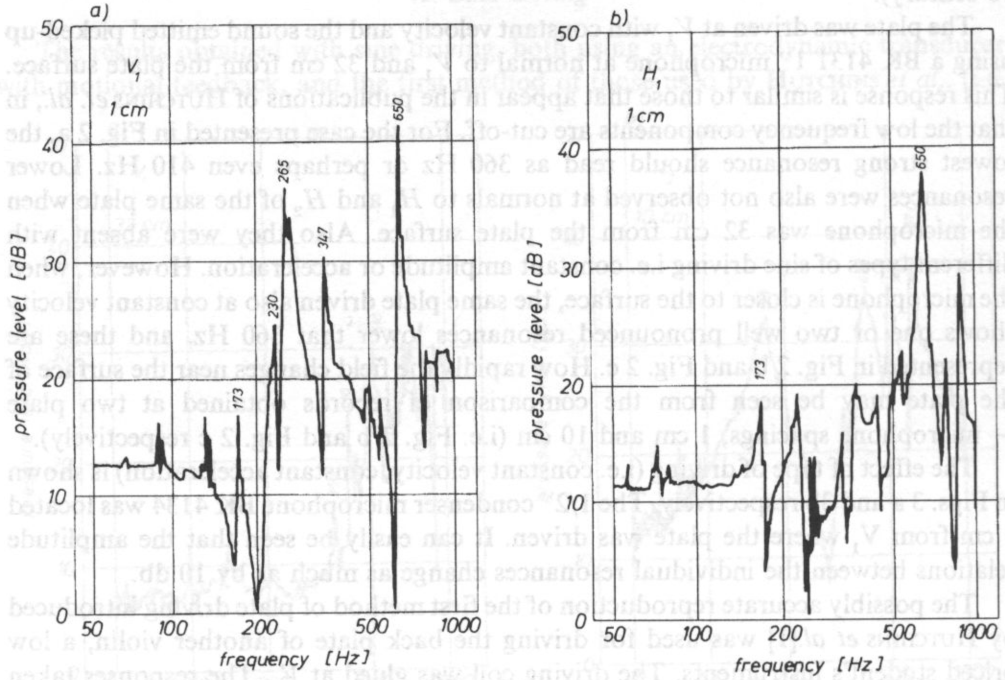


Fig. 3. The effect of driving, i.e. constant velocity *a)* and constant acceleration *b)*.

from V_1, H_1 and H_2 using a BK 4145 1" microphone 1 cm from the plate are presented in Figs. 4 a, 4 b and 4 c respectively.



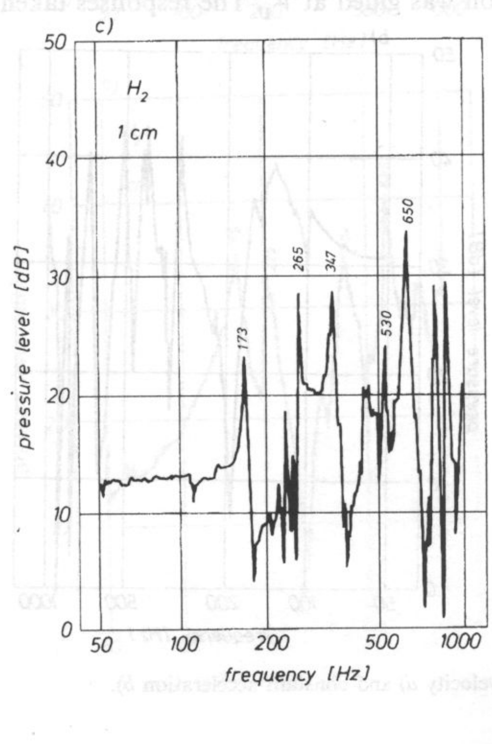


Fig. 4. The effect of microphone location relative to the plate. (Coil driven plate, the method of Hutchins *et. al.* 1976).

The effect of microphone placing along the plate can be seen in these results. It is evident that for V_1 the lowest strong resonance may well read 265 Hz whereas for H_1 it is 650 Hz for and H_2 perhaps 265 Hz. It seems worth pointing out that, whilst for H_2 the subsequent resonances are at 173, 265, 347, 530 and 650 Hz, for H_1 all resonances except for 650 Hz are strongly suppressed.

The responses picked-up the same way from the same back plate, but driven by electrodynamic transducer with constant velociti at V_1, are presented in Figs. 5a, 5b and 5c for pick-up points V_1, H_1 and H_2 respectively. The differences in these types of response are also observed particulary with reference to the relative pressure levels at the subsequent resonances. In all these cases, however, the pressure level for the lowest resonance at about 154 Hz is always substantial. Note that the microphone spacing in Figs. 5 a to 5 c is always 1 cm.

The differences observed between the data presented in Fig. 4 and Fig. 5 result both from the use of a different driver and its frequency response, and from the load of the plate introduced by the driver, which in both cases was different. In the case of an electrodynamic transducer with motional feedback the driving was constant over the frequency range investigated.

B. Tap tones

The results of the frequency analysis of tap tones picked up close to the plate surface and recorded on magnetic tape are presented in Figs. 6 to 9. The three curves presented in each figure were obtained using the same holding point, i.e.: V_1 in Figs. 6 and 7, H_1 in Fig. 8 and H_2 in Fig. 9. Holding, tapping and pick-up points are specified in the insets near each curve. The frequencies of the subsequent main resonances are indicated as read from the digital counter while the analysis was run. All twelve variants of holding, tapping and listening were repeated and the pitch of the tap tones was determined by very well trained expert subject, a violinist with about 10 years experience in psychoacoustical experiments pertaining mostly to pitch perception. Median values of his pitch judgements of tap tones, based on 10 to 12 subjective comparisons with the tones of a properly tuned violin, are given above each curve (open triangles), together with corresponding pitch in equal temperament (A_4=440 Hz) scale. Two variants (Figs. 6 a and 6 c) were additionally judged by a group of six musicians, highly experienced in psychoacoustic experiments concerning pitch perception. The musicians based their estimations of pitch on comparison with a tuning fork. The answers were from E_4 to F_4 for the first variant and from A_3 to B_3 for the second. The corresponding frequency ranges are represented in the drawings by horizontal bars. Median values were B_3 and E_4 correspondingly, thus equal to the medians computed for the first expert.

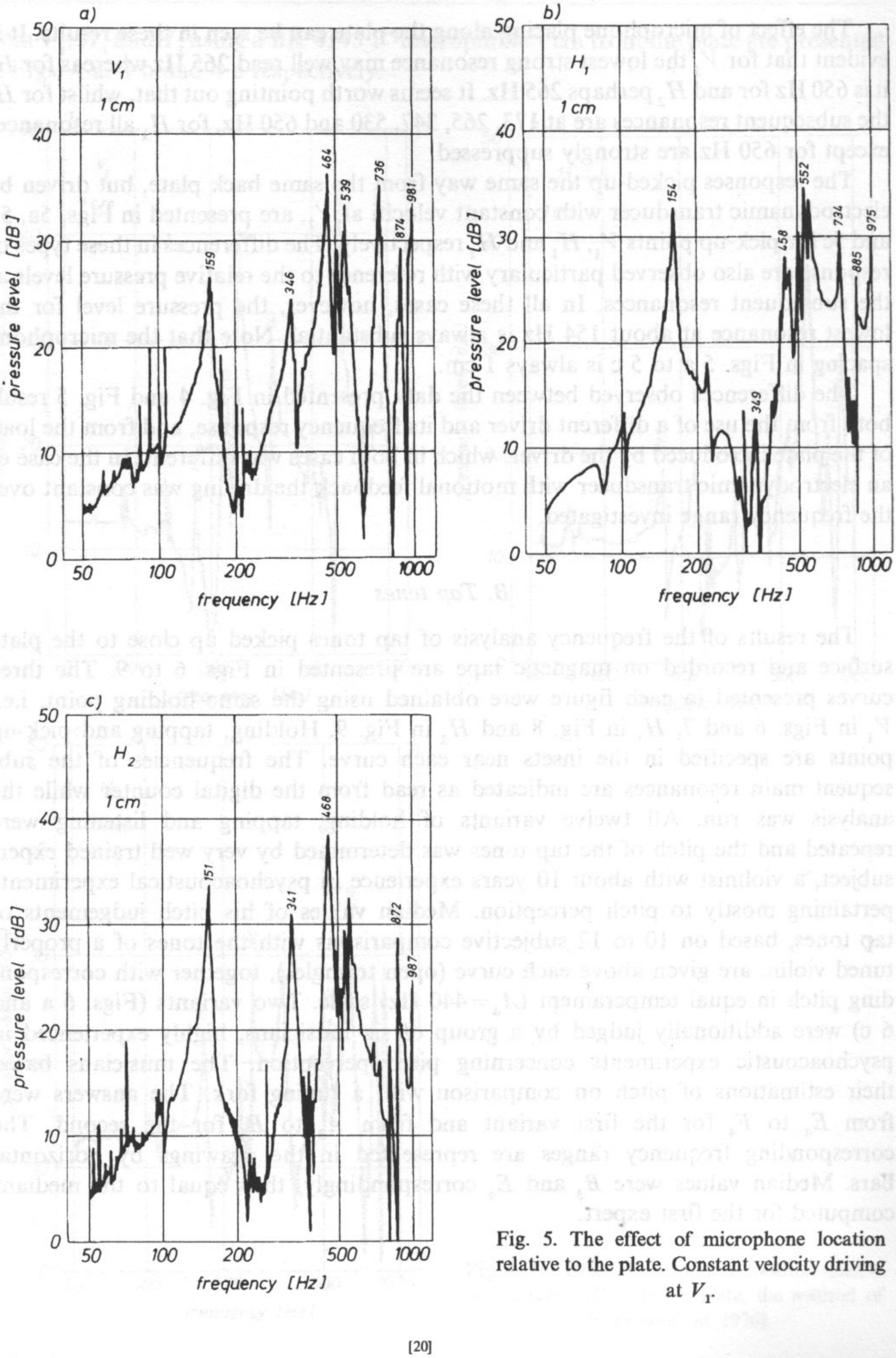
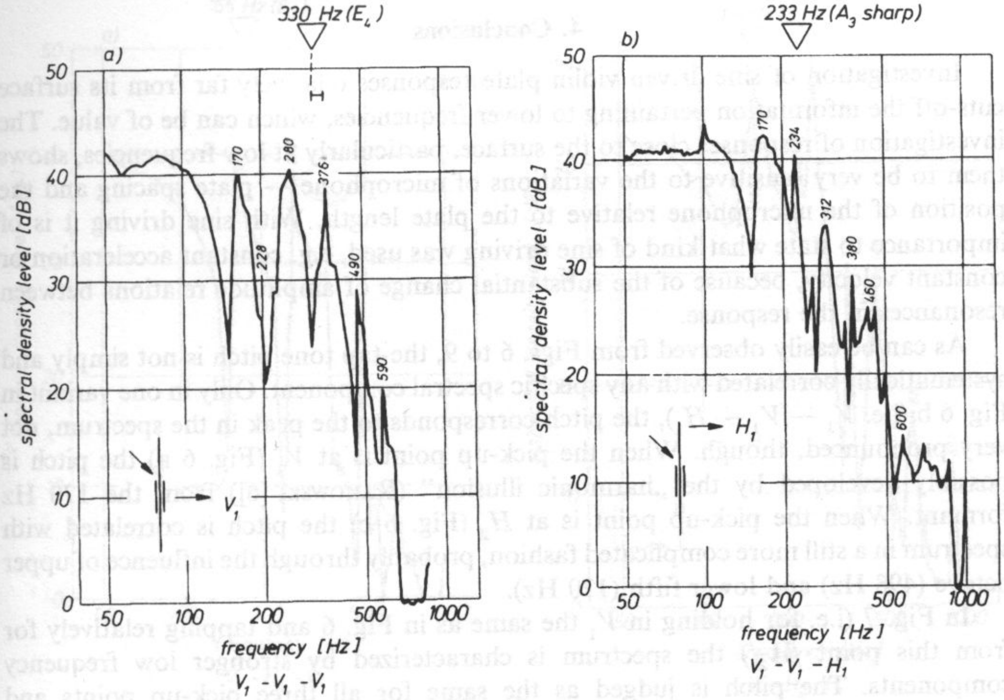


Fig. 5. The effect of microphone location relative to the plate. Constant velocity driving at V_1.



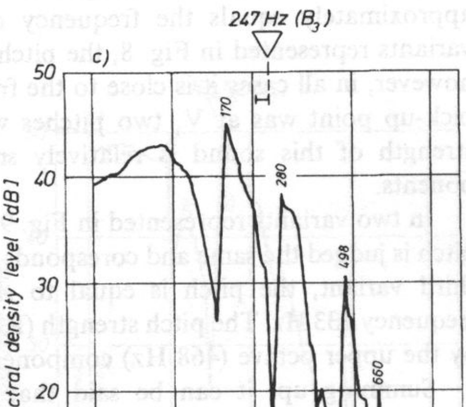


Fig. 6. Tap tones spectral density and pitches as dependent on the place of microphone location and listening. Plate held and tapped at V_1. Pick-up points as indicated in the insets.

4. Conclusions

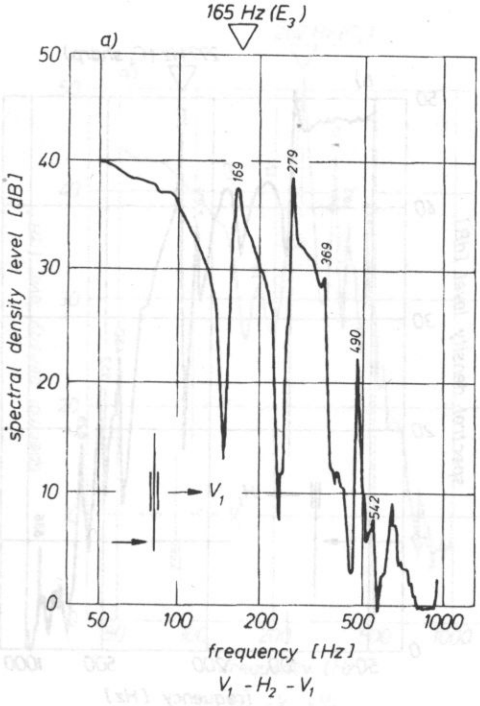
Investigation of sine driven violin plate responses relatively far from its surface cuts-off the information pertaining to lower frequencies, which can be of value. The investigation of responses close to the surface, particularly at low frequencies, shows them to be very sensitive to the variations of microphone — plate spacing and the position of the microphone relative to the plate length. With sine driving it is of importance to state what kind of sine driving was used, e.g. constant acceleration or constant velocity, because of the substantial change of amplitude relations between resonances in the response.

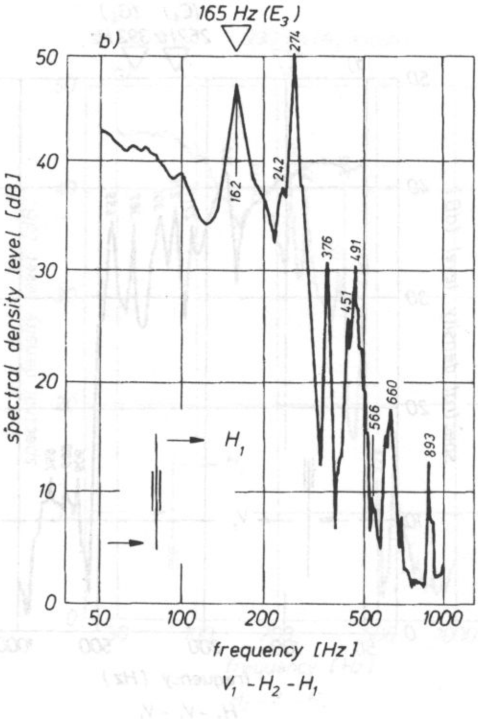
As can be easily observed from Figs. 6 to 9, the-tap tone pitch is not simply and systematically correlated with any specific spectral component. Only in one variant in Fig. 6 b (i.e. $V_1 — V_1 — H_1$), the pitch corresponds to the peak in the spectrum, not very pronounced, though. When the pick-up point is at V_1 (Fig. 6 a) the pitch is possibly developed by the „harmonic illusion" (Rakowski [6]) from the 170 Hz formant. When the pick-up point is at H_2 (Fig. 6 c) the pitch is correlated with spectrum in a still more complicated fashion, probably through the influence of upper octave (498 Hz) and lower fifth (170 Hz).

In Fig. 7 (i.e. for holding in V_1 the same as in Fig. 6 and tapping relatively for from this point /H_2/) the spectrum is characterized by stronger low frequency components. The pitch is judged as the same for all three pick-up points and approximately equals the frequency of the lowest component. In all the three variants represented in Fig. 8, the pitch is strongly dependent on the pick-up point, however, in all cases it is close to the frequencies of strong components. Only if the pick-up point was at V_1 two pitches were judged as equally strong but the pitch strength of this sound is relatively small due to a number of equivalent components.

In two variants represented in Fig. 9 (i.e. $H_2 — V_1 — V_1$ and $H_2 — V_1 — H_2$) the pitch is judged the same and coresponds to strong components in the spectrum. In the third variant, the pitch is equal to A_3 sharp which corresponds to component frequency 233 Hz. The pitch strength (Rakowski [5]) in that case is probably amplified by the upper octave (468 Hz) component.

Summing up, it can be said that in investigation of both, sine driven and tapped violin plate responses, very precise description of experimental conditions is required. This refers particulary to the type of sine driving and to the points where the plate is held, driven and the sound picked-up as well as to the microphone — plate spacing. The tap-tone pitch may not always correspond directly to the frequency of strong components but may be in harmonic or quasi-harmonic relations with them.





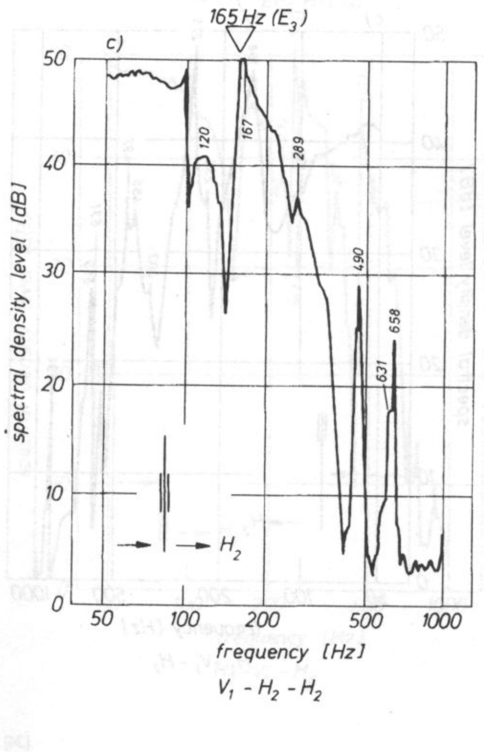
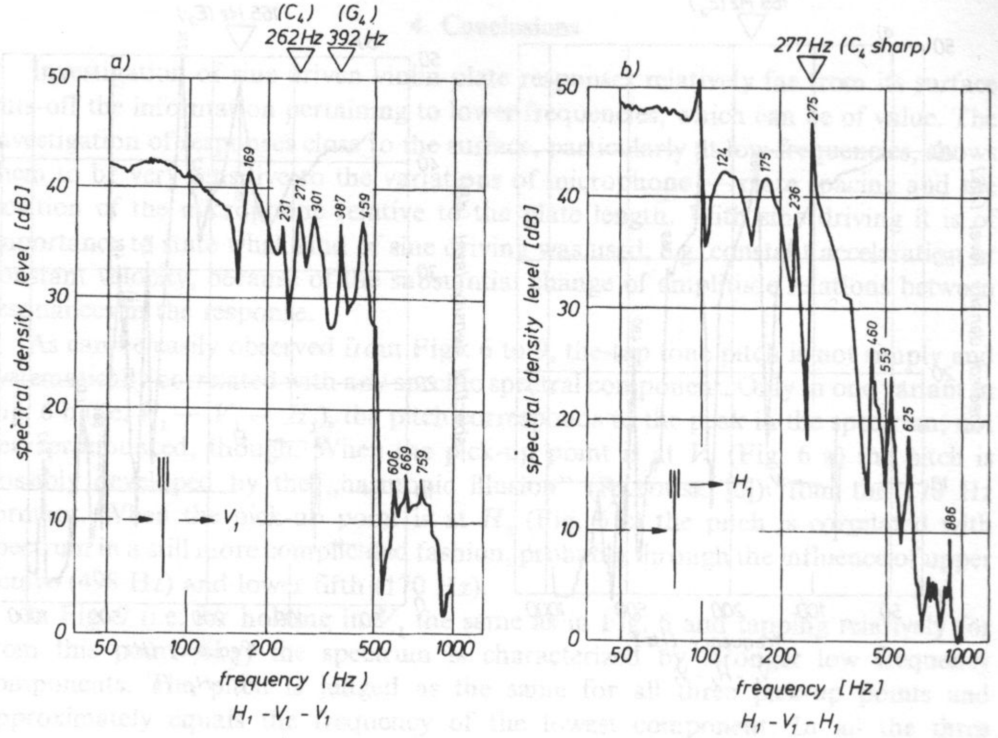


Fig. 7. Tap tones spectral density and pitches as dependent on the place of microphone location and listening. Plate held at V_1 and tapped at H_2. Pick-up points as indicated in the insets.



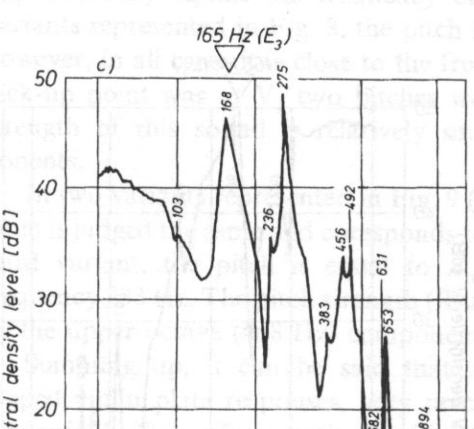


Fig. 8. Tap tones spectral density and pitches as dependent on the place of microphone location and listening. Plate held at H_1 and driven at V_1. Pick-up points as indicated in the insets.

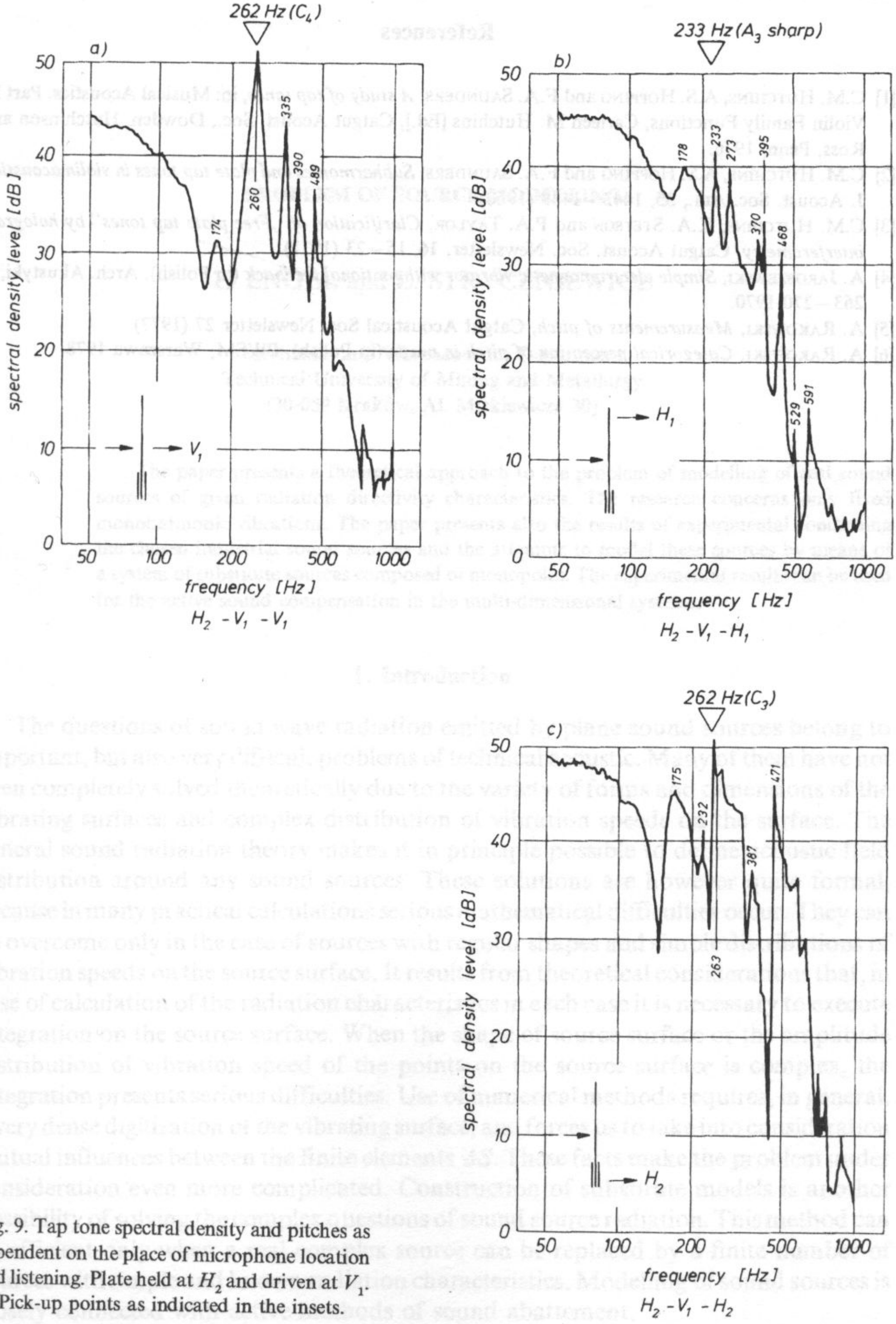


Fig. 9. Tap tone spectral density and pitches as dependent on the place of microphone location and listening. Plate held at H_2 and driven at V_1.

Pick-up points as indicated in the insets.

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