Revised
AAMIM 001 . Doc

SOME VIOLIN RESPONSE CURVES
and
WHAT DOES THE SOUNDPOST DO

The violin body has a number of resonances that are excited by energy fed into it. Some of the ways this can be done are; continuously by means of a bow applied to the strings of through a transducer attached to the bridge (or somewhere else) and supplied with a signal from an amplifier driven by a source. The source is usually a signal generator that supplies a single tone that can be varied in strength and frequency. Discontinuous energy input can be achieved by plucking a string, or by tapping some part of the instrument. The tap could be delivered by the finger or mechanical means.

The bow excites the string into vibration and generates a number of string harmonics, the strengths of which are delivered to the top plate of the instrument as forces at the two feet of the bridge. The displacement resulting is largely at the left foot of the bridge since the right foot is almost immobilised by the soundpost. There is a reaction at the right foot but the motion is much less than at the left foot. The violin body in turn vibrates in a number of modes if they correspond approximately to the harmonic frequencies. The low frequency body modes will have an antinode at the left foot of the bridge and a node near the right foot because of the presence of the soundpost. At higher frequency harmonics this nodal point may not be so important. In fact the right foot may be at the antinode of quite high frequency harmonics. The soundpost also may transmit more energy to the back at these frequencies.

The continuous excitement of the bridge by a transducer fed with a single variable frequency tone (often with the strings damped to eliminate string modes when only body modes are being studied) explores the resonance peaks (and antiresonance troughs) as a function of the excitation frequency. If (for a constant strength input signal) the response at the point of excitation is recorded with an accelerometer (usually built into the excitation transducer) we can express the result either in terms of the variation in acceleration using the raw signal, or velocity (mobility) or displacement by successively integrating the signal from the accelerometer. If the accelerometer "pickup" is placed somewhere else on the instrument we will record the transfer response which will be different to that at the input and vary, depending on where the accelerometer is situated in respect to the modal shapes of the violin body. Those resonance peaks will be absent that have a nodal line at the position of the accelerometer since they will not be detected.

The reactiion of the body to a continuous input signal as described above, say, at the bridge, could be recorded using a microphone to measure the strength of the sound produced. The strength of the measurement would depend on the location of the microphone; the distance away and the position with respect to the directivity of the violin. Barring an anechoic chamber and averaging the output from 6 microphones placed at strategic positions, the best compromise appears to be 1 microphone in front of the violin in a moderately reverberant room with no standing waves possible i.e. the violin placed in an asymmetrical position in the room and a mixture of reflecting surfaces and drapes (carpet) and a room of irregular shape if possible.

The sound recorded would be from those resonances at low frequencies that had a predominant monopole content i.e. acted as a simple source, while at higher frequencies dipole and higher multipoles would increasingly radiate efficiently because of the greater radiating directivity of a source at high frequency. Some body modes e.g. beam modes, body torsion, etc. would not contribute to the sound output because they could not act as a "simple source" (equivalent to a pulsating sphere) by virture of the shape of the mode. These frequencies, incidentally, are below the range of the instrument.

If the response of the violin is recorded from an accelerometer mechanical vibration modes that do not contribute to the sound will also be recorded.

Impulse excitation (tap) can also be recorded by an accelerometer placed at the input or another location to give the input response or the transfer response. Figure 1 shows response curves obtained by analysing the signal resulting from a controlled tap delivered to the E-string edge of the bridge by a pendulum (5 samples were averaged). In contrast to the excitation of the violin with a single frequency continuous tone which only indicates the response of the instrument at the applied frequency, a tap excites all the resonances "visible" at the location of the tap. The location chosen on the bridge is close to the position and direction of bowing so that most of the energy would be transferred to the top at the left foot. At most frequencies this is an antinodal point so most resonances will be excited. In the figure the top curve is a mobility plot from a magnet/coil pickup at the G-string edge of the bridge. The other 3 curves are drawn from a microphone signal taken in front of the violin. The first of these (as for the top curve) is plotted on a dB (log) scale as is the bottom curve. The remaining curve is plotted on a linear scale. The logarithmic plot appears to compress the data towards the top and expand it towards the bottom of the figure. The logarithmic plot is closer to the way the ear registers the sensation of sound, compressing the loud sounds and being very sensitive to low intesity sounds.

There are some differences between the mechanical mobility plot at the top and the next one obtained with the microphone. For example, at about 250 Hz the first curve shows 3 peaks while only one is recorded with the microphone. This one is the main air resonance. The other two peaks will be non-sounding modes. One could be due to the fingerboard which is tuned to be close to that of the main air peak. The peak at 480 Hz, while being the highest in the mobility plot, is a little below the height of the 540 Hz peak in the microphone plot suggesting that its monopole (or breathing) content is not as high as the 540 Hz peak. The peak at 600 Hz has a relatively low mobility but a high sound output.

The 1/3 octave plot at the bottom of the figure shows the relative prominence of groups of peaks and their effect on sound quality more related to timbre. In this plot, as in the other log plots, diferences only are significant and absolute values cannot be inferred from the curves. The linear plot, on the other hand, can give absolute values after suitable calibration which has not been done in this case.

THE SOUNDPOST

The soundpost does two things; it adds stiffness to the violin body and it introduces an asymmetry to the modes of vibration thus increasing the monopole, or breathing, action of the body. The force delivered to the back of the violin by the soundpost is not in phase with that experienced by the bassbar side of the instrument. If the soundpost were of infinite stiffness and zero mass they would be closer to being in antiphase. We get close to this ideal with low density and high modulus spruce. The progress of an elastic wave in the back is slower than in the top by virtue of the higher density of maple and it starts off about 100 us later. The effect of the soundpost cannot be studied in isolation but in conjunction with the sides. Above about 1 kHz the normal soundpost is more compliant than the ribs. For the same ribs, soundposts of lower stiffness will become more compliant at lower frequencies. It seems the effect of this is to reduce the output from the lower strings. How this effect is modified by changing the position of the soundpost is not yet known. One study suggests that moving the soundpost towards the f-hole lowers the stiffness of the body; towards the centre raises it.

Something on the fit of the soundpost might be of interest. The slope at the ends are made to match that of the inside of the top and back in the region where it will be placed. These slopes can be measured before the plates are assembled. Otherwise some other method is needed. Chalking the ends of the roughly prepared post and a trial fit are an option. Pencil carbon paper somehow inserted to mark the high spot on the ends of the post is another possibility. It must be remembered that a properly prepared soundpost i.e. as to length and end slope, will only fit at one position without being either slack or too tight except for a short distance parallel to the centre joint. Deviation from this position, including tilt, will change the contact to a point at each end of the post. Attempts at rotating the post will indicate this. This assumes that there is no deformation of the surfaces in contact. The endgrain of the soundpost as normally cut has twice the hardness of the surface of the top in contact with it and about half the hardness of the maple surface. Some indentation of the top plate is therefore expected. Without the soundpost the output from the two lower strings is greatly reduced as was found by Felix Savart in 1824.

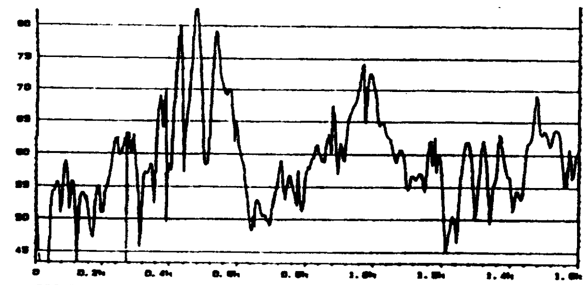
HARMONIC ANALYSIS

Samples can be taken from bowed notes whether open or stopped and analysed for their harmonic content using a spectrum analyser. All the graphs in this paper have been obtained with a B & K model 2032 Spectrum Analyser but programs for FFT's can be obtained for PC's to do similar things not quite so well. An example of the harmonics, for the violin used in figure 1, of the four open string sounds are given in figures 2 and 3. In figure 2 the fundamental is marked by the cursor line and it will be noted that the fundamental is weak on the G-string. This is normally the case. Where the fundamental is weak the presence of a number of harmonics supplies the interval that enables the ear to provide the fundamental and correctly pitch the note. The logarithmic plot gives a better representation of what the ear hears than the linear plot for the reasons stated above. It is clear that there are an abundance of harmonics present and considerable lattitude in their relative strengths to give acceptable sound quality. The linear plot of the same data in figure 3 gives a disturbing first impression until a correct interpretation is made. Comparisons between strings is limited because of the absence of calibration other than an attempt to be consistent when recording the notes.

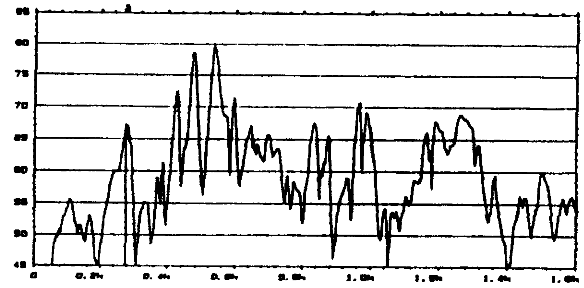
For comparison, figure 4 shows the harmonic content for 3 famous violins of the open G-string sound taken from the STRAD CD of the "Glory of Cremona". On the CD Ruggiero Ricci plays a test sample on each of the 15 violins which includes the opening ascending phrase from Bruch's G minor violin concerto which starts with a long open string note. It appears to be free of any vibrato. The plots shown in figure 4 are typical of the 15 instruments. The features to be noted apart from the variable height of the harmonics, are the relatively strong fundamental and the absence of harmonics above 4 - 5 kHz. Some of the violins had harmonics extending beyond 5 kHz. It would be interesting to learn the reason for these two features. Is the strong fundamental due to a resonance at 200 Hz? Is the "cut off" at 4 kHz a function of the instrument or due to the influence of the bow? It would be of interest to have sounds from the other strings. In this regard we do have a sample from the A-string of "Il Cremonese" a Stradivari of 1715 up to 5 kHz showing similar features to those in figure 2 above. In a response curve, also in the same publication, there is no resonance at 200 Hz, the first prominent peak being the air peak at about 260 Hz. This data appears in a book "Strumenti di Antonio Stradivari" published in 1991 by Editrice Libreria Turris, Cremona.

It would seem that because of the variation in the detail of the response curve and the strengths of the harmonics in the bowed string sound with changes, for example, in the setup that only major features could be used to distinguish an instrument. Since there is such a variation in the fine detail of the response curve it is not easy to judge the quality of a good violin except in the broadest sense. The presence of a strong air resonance and other strong body peaks is as much as can be expected. Other second order relationships that seem to be needed for exceptional instruments require additional measuring techniques. Variations on the 1/3 octave plot, which have been used since the 1930's would seem to be a useful link between the response curve and the sound assessment. It would also seem that the final weight of the violin may be a good first indicator of the ease of response.

J.E. McLennan



SETUP V8 VIOLIN 1 S/POST 111 KG/S UD CHINREST MAG/COIL PU



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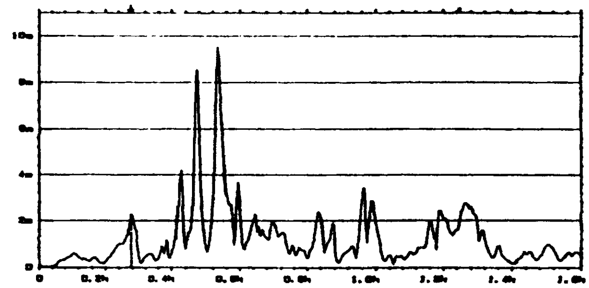

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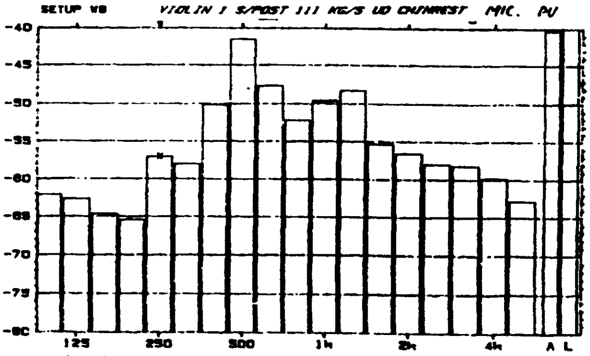
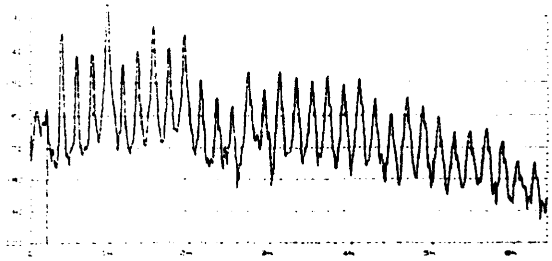


violin 1 s/post 111 kg/s MIC. PU



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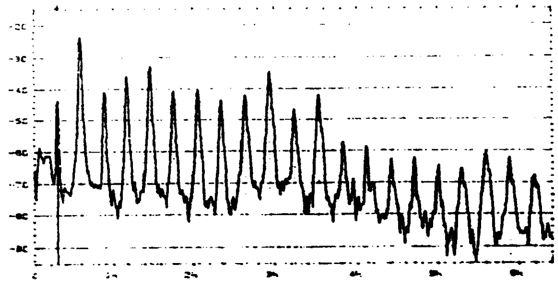

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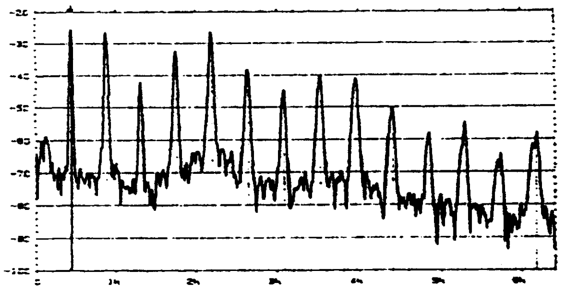

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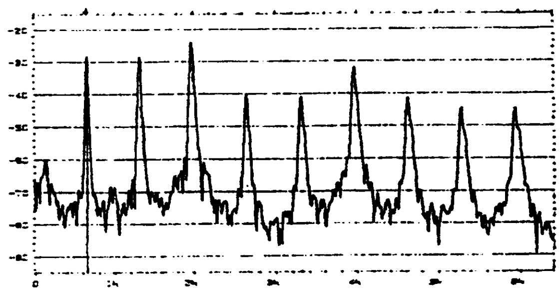

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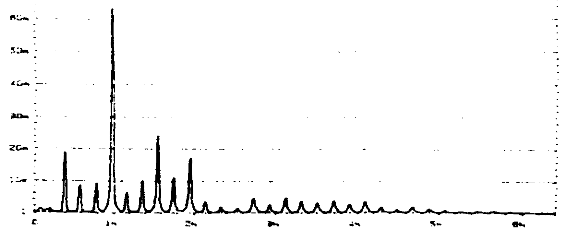

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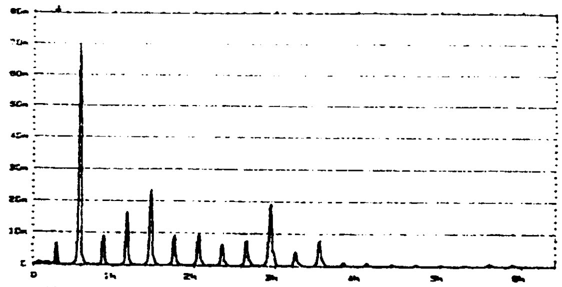

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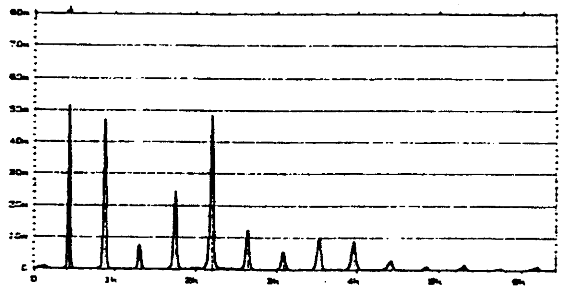

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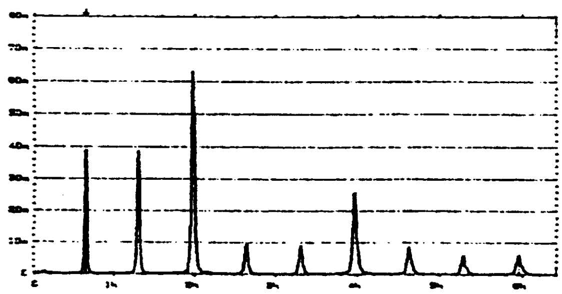

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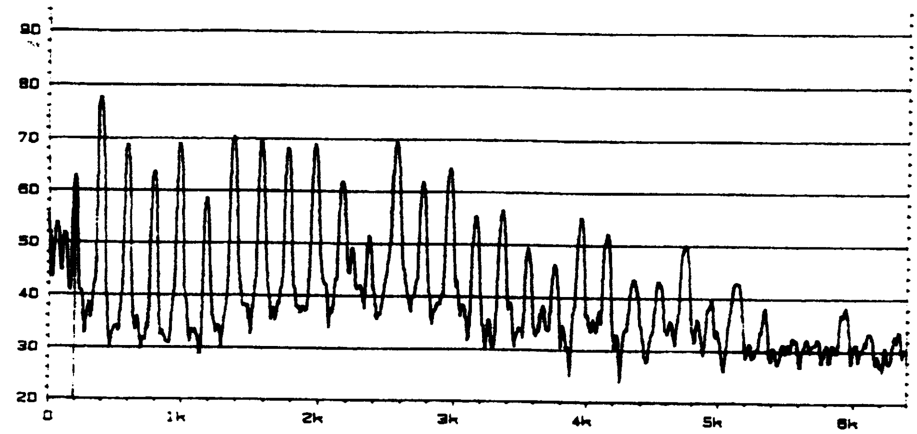

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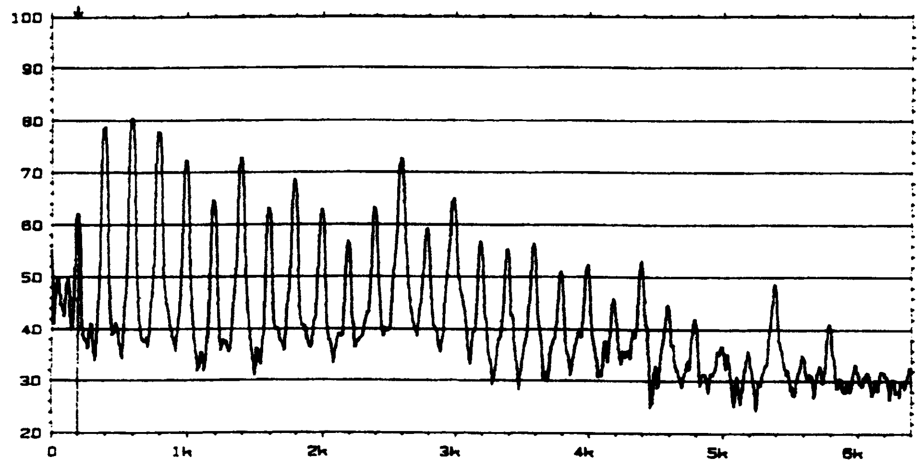

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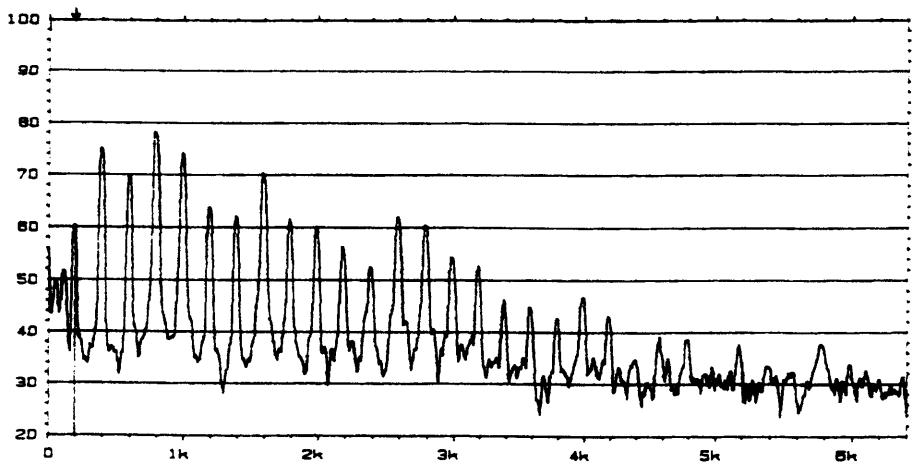

SETUP W1 *J. GUARNERI DEL GESU 1739 G STRING*