Several Measurements on Stressed Resonators
--- from Violin without sound post up to Bell Cricket

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Several different kinds of "STRESSED RESONATORS" are investigated. With the installation of a sound post a violin's tone enriched not only in physical amplitude but also the autocorrelation function parameters and inter aural cross correlation parameters are "amplified". The measurement for a simple model system with single STRESSED RESONATOR shows various possibilities in this direction.

Key words: violin, sound post, stress, resonator, autocorrelation function (ACF), Interaural cross-correlation function (IACF)

1. INTRODUCTION

"Sound post" is a tiny piece of wood installed within the body of a string instrument. The ancestor string instruments in Mongol had no such structure. With installation of such tiny part, the whole sound of a violin completely changes, from weak oscillation of strings to strongly musical sound.

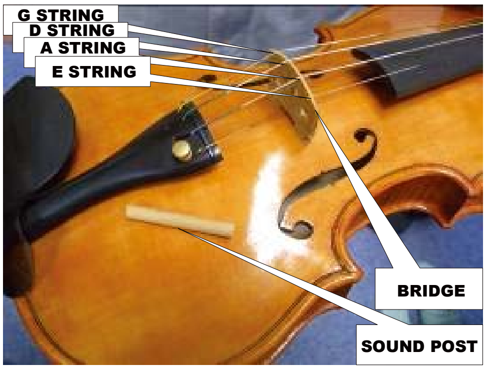

Fig. 1-a Violin and sound post

Fig. 1-b Installation of sound post into a violin.

It is certain that installation of sound post makes certain kind of "amplification" for the sound of a violin. This "amplification", however, does not always mean the mere increase in physical amplitude of sonic wave.Fig. 2-a 2-b are the wave forms of a violin at a binaural measurement "WITH" and "WITHOUT" sound post, measured in anechoic chamber. Seemingly the difference between those two is small. Here binaural autocorrelation function (ACF) measurement clearly shows the difference (Fig. 2-c and 2-d).

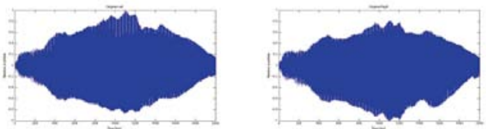

Fig. 2-a.Wave forms of a Violin WITH sound post, LR.

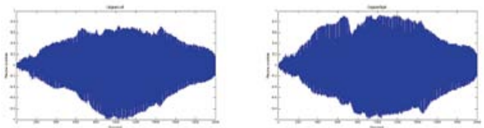

Fig. 2-b. Wave forms of a Violin WITHOUT sound post, LR..

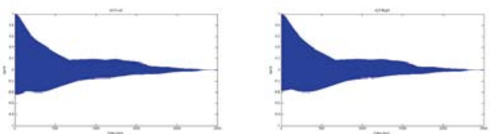

Fig. 2-c. ACF of a Violin WITH sound post, LR.

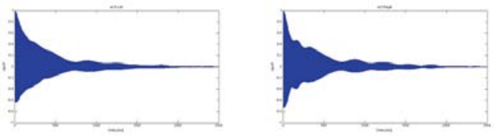

Fig. 2-d. ACF of a Violin WITHOUT sound post, LR.

Fig. 3 is an example of quantitative evaluation of physical sound levels of a violin, played with the same violinist. The DOTS indicate WITH sound post (blue : Left ear, red : right ear) and the CIRCLES points WITHOUT sound post, respectively, whose wave forms are seen in Fig.2.

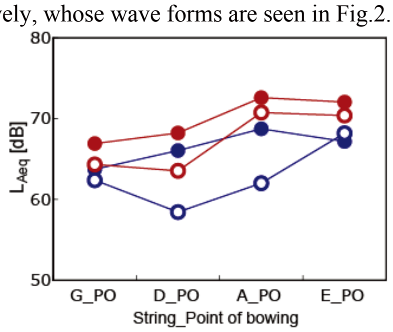

Fig. 3. Quantitative evaluation of sound levels WITH and WITHOUT sound post in a violin, played with a violinist.

Fig.3 clearly shows that with the installation of sound post, the sound level certainly increase (in Fig.3 from CIRCLES to FILLED CIRCLES, in each color) but they remain in the same range of power and the difference is no more than 10 dB. However, the subjectively LISTENED difference between those two is heard much larger.

Fig. 4 is the effective duration of the autocorrelation function τ_e [1] calculated from the same data to Fig. 3.

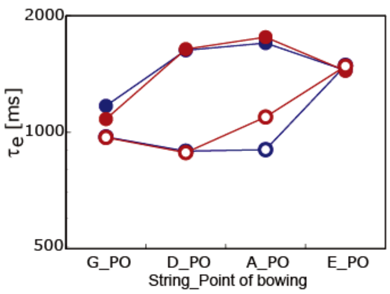

Fig. 4. Quantitative evaluation of effective duration time τ_e WITH and WITHOUT sound post in a violin, played with a violinist.

Here the difference is quite clear; the installation of a sound post almost doubled τ_e, from 1000 msec to 2000 msec.

With an installation of sound post, two surface boards of a violin would be coupled with some addition of STRESS. Such "AMPLIFICATION" is also observed with single resonating board. We would like to call this "STRESSED RESONATOR" effect in this paper.

We have also found such STRESSED RESONATOR structure, quite similar to a sound post in a violin, even in the fundamentals of certain Japanese wooden Buddhist temple. This suggests that in traditional craftsmanship, this "STRESSED RESONATOR" effect --- cognitive "AMPLIFICATION" with less physical power --- had known in various scale, from musical instrument to large building [2].

2. MEASUREMENT OF MODEL SYSTEM, RESULT AND DISCUSSION

2.1 Model resonating system using plastic board and a music box

In the field of music instrument acoustics, the vibration of a violin is usually measured with impulse-reaction measurement [3]. After many tests, we had measured simplest case of model resonating system.

A plastic board (365mm x 257mm, 0.5mm-width) is attached to a music box ("Opus Silver" produced by SANKYO co. Japan) as the sound source. Just like the cases in the recent advanced Violin engineering, "impulse-reaction-like" measurements would clearly realize the "STRESSED-RESONATOR" phenomena. Also for the calculation of ACF parameters, sound sources like a music box is suitable, for the sound is not continuous but point-wise; impulse and reverberation. We used a pair of microphones, installed into a dummy head to measure and calculate binaural parameters. First, we have measured the "bare" music box. Then secondly attached to the plastic sheet WITHOUT STRESS, and finally add STRESS to the sheet. About the attachment, we have done preliminary experiments and the most effective condition was selected. The stresses are adapted to the plate with thread, clamps and clips We dare select this method because there is a strong non-linear characteristic in the adaptation of the "pulling" through the thread to the plastic sheet; with only a little "pulling", the gain of this system rapidly saturates, and remains near the maximum. (Fig. 5-a.5-b)

Fig. 5-a. Music box used in this model measurement (The photo of Fig. 5-a is upside-down).

Fig. 5-a. Music box used in this model measurement.

Fig. 6-a, b, c are the wave forms of the music box sound at a: without resonator, b: attached to plastic sheet which left free without "pulling" and c: adapted stress with the "pulling".

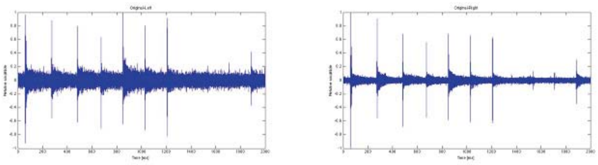

Fig. 6-a. Wave forms of "BARE" music box sound, LR respectively.

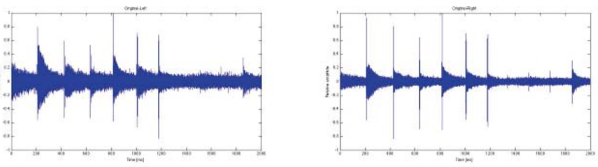

Fig. 6-b. Wave forms of music box sound attached to "FREE" plastic board, LR respectively.

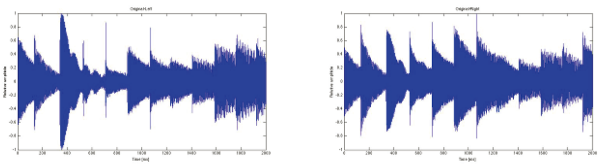

Fig. 6-c. Wave forms of music box sound attached to "STRESSED" plastic board, LR respectively.

Fig. 7-a, b, and c. are the values of ACF calculated from the same data to Fig.6-a,b, and c respectively.

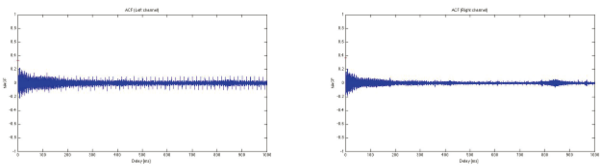

Fig. 6-a. ACF of the "BARE" music box sound, LR respectively.

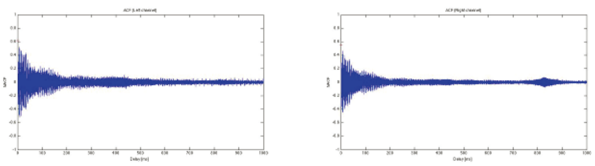

Fig. 6-b. ACF of music box sound attached to "FREE" plastic board, LR respectively.

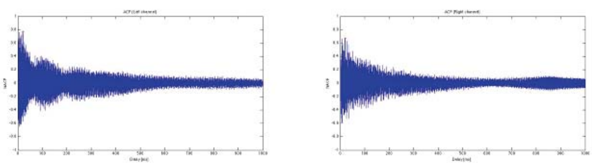

Fig. 6-c. ACF of music box sound attached to "STRESSED" plastic board, LR respectively.

Just like cases of violin sound WITH and WITHOUT sound post, we would like to evaluate the difference in these three cases in quantitative manner. Fig. 7 is the listening levels of this model system.

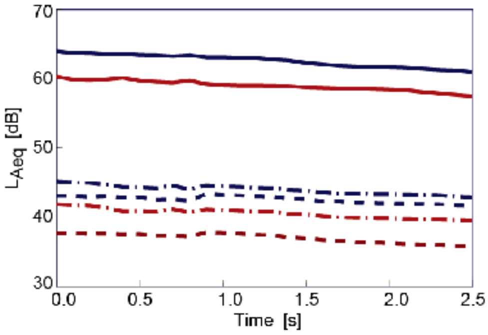

Fig. 7 Changes in listening levels of the Model System

Dots indicate "BARE" case; Broken lines "FREE", lines "STRESSED" and blue: left ear, red: right ear respectively. The gain obtained by attaching to FREE plastic sheet is no more than 5dB, where the adaptations of STRESS increases the gain more than 15 dB. The total gain reached more than 20 dB. In this model case the physical amplification of sonic wave is also much stronger than that in the case of a violin instrument.

Fig. 8 is the change of ϕ_1, the amplitude of the first maximum peak of the ACF.

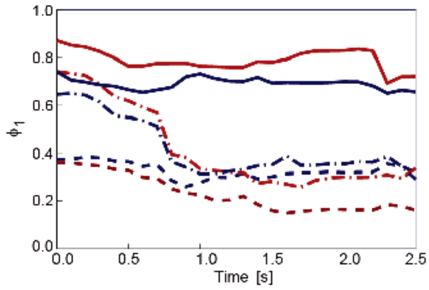

Fig. 8 Changes of ϕ_1, in the Model System.

Fig. 8 clearly shows the difference between "BARE & FREE" and "STRESSED" condition. In the "BARE" case there is little change in ϕ_1 so that we can not listen the EFFECTIVE AMPLIFICATION caused by the system; as the music box is disconnected to the resonator, it is quite natural. With the attachment to the FREE plastic sheet, ϕ_1 shows interesting changes, once increases to remarkable extent, but suddenly decays and within no longer than 800 msec. reaches to almost the same level of BARE music box. Now, a striking difference is observed in the cases of STRESSED resonator. Not only ϕ_1, increases much more than in the cases of FREE plastic sheet, but they remains in the high level more than 2000 msec. This shows a possibility of continuing enhancement caused by the STRESSED RESONATOR; COHERENT OSCILLATION would make possible such long-lasting ϕ_1, and thus, long effective duration time τ_e. In the cases of optics, such "time-dependent coherence of source wave" causes LASER oscillation, with the effective use of quantum energy levels of molecule [4]. It is clear that in our model case here, phenomenon has little to do with molecular energy levels, but there could be similar time-dependent dynamical enhancement of the source wave in possible nonlinear way.

With the binaural measurement IACF analysis tells us another remarkable characteristic of this STRESSED-RESONATOR.

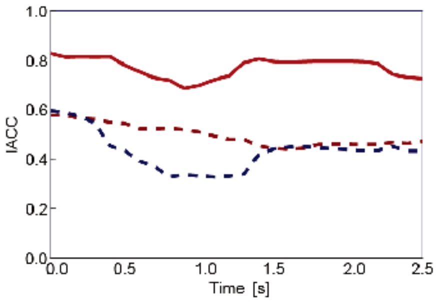

Fig. 8-a Changes of IACC in the Model System.

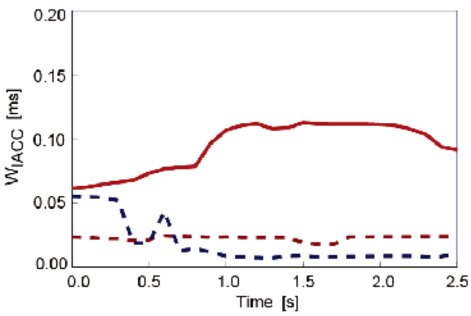

Fig. 8-b Changes of W_{IACC}, in the Model System.

W_{IACC}, is understood as good index of the human auditory sense of sound localization [1]. Low value of W_{IACC} tells us the localization of the sound source and high value of it the BREADTH of the sound. We can easily tell, from the tiny music box's sound where it locates. The STRESSED RESONATOR "broaden" the localization and even "enrich" the quality of sound. This kind of aspect is not easily got from the spectral analysis to such system, as long as the instrument acoustics including violin sound study. Binaural measurement and ACF analysis to SINGLE STRESSED RESONATOR reveals such remarkable characteristics. Now we would like to remember that a violin instrument does not use single system, but a pair of COUPLED STRESSED RESONATOR system. We would like to continue fundamental study for this, and now only to show an example from natural creature.

Bell Crickets are tiny insects whose weight is no more than 1gram but their SONGS are quite intense and strong.

Fig. 9 A bell cricket.

Our group are trying to analyze the mechanism of bell cricket's "singing mechanism" from the stand point of STRESSED RESNATOR, and also trying to design loudspeakers based on this new principle.

3. CONCLUDING REMARK

There is significant gap between the reality of HUMAN LISTENING and PHYSICAL OSCILLATION of the air; SONIC WAVE. The examples we introduce here tell quite eloquently the limitation of 1) monaural (not binaural) 2) only spectral (not time-dependent) 3) linear and 4) mechanical (not cognitive to living creature, even also to tiny insects! for they must communicate important information for their life!!) approaches to the sound. The (high) quality of musical sound had been also discussed as "subjective issues" but with careful application of subjective preference theory there is vast amount of possible reality in sound to be revealed, which could also fully utilized for new human innovation

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NOTES AND REFERENCES

[1] Ando Y.,(1998) Architectural Acoustics: Blending Sound Sources, Sound Fields, and Listeners Springer-Verlag, New York.

[2] Prof. Laura MAURI at the Pavia University had pointed out possibilities of utilizing this STRESSED RESONATOR effect in Catholic churches, especially in the interior wooden ornaments, and also in the structure of pipe organs. We would like to start a research soon, on this point of view, with the Italian groups from Pavia, Cremona, Milano and Bologna.

[3] The authors would like to show best thanks, about the information of recent advanced methodologies in violin-making, to Maestro Claudio AMIGHETTI, Maestro Roberto REGASSI and kind advice from Prof. Alessandro COCCHI and Maestro Marco CESARE. For more, see Cingolani S.,(2008) Acustica musicale e architettonica, Citta Studi.

[4] See Feynmann R.P.,(1964) "The Feynman Lectures on Physics", Addison Wesley, Longman.