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ABOUT INFLUENCING AN ACOUSTIC RESONATOR ON THE DYNAMIC CHARACTERISTICS OF A GUITAR SOUNDBOARD

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The paper presents the results of numerical-experimental investigations of influencing the acoustic internal cavities (resonator) on spectrum of the eigenfrequencies of a guitar soundboard. With the help of a system for vibration diagnostics the set of time-digital sequences (acceleration from time) is obtained. On the basis of methods of digital spectral analysis the spectral concentration of power estimated. The relations for the soundboard with allowance of a resonator and without it in range up to 1000 Hz are obtained. It is stated, how the presence of the resonator influences dynamic characteristics of a soundboard of an acoustic guitar.

The wide experience has been accumulated and the definite traditions have been formed in the field of creation of musical instruments (MI) for many centuries. The main design parameters of MI have been established by trial and error. Apparently, that the further perfecting and developing of MI can be connected with development and perfecting of mathematical modeling methods. In this connection the computational finite-element model of frame elements of string MI is being elaborated in our works [1, 2]. It should be noted that a string MI is a coherent elastic-acoustic system. Thus the strings of MI are a source of mechanical oscillations, soundboard is a main radiator of sound oscillations, and an acoustic internal cavity is a resonator of sound oscillations. The elastic vibrations of strings, soundboard, sound oscillations of air pressure are intimately connected with one another. However each of these elements is traditionally investigated separately. The purpose of the given work is to evaluate value of influencing acoustic internal cavity on a spectrum of the eigenfrequencies of a soundboard.

The conducted earlier experimental research of forced mechanical oscillations of a soundboard has allowed receiving a cumulative resonance curve (RC) for a soundboard with a resonator [1]. The comparative analysis of calculation and experiment (eigenfrequencies) results has shown their mutual conformity. In the work [2] the spectrums of resonance amplitudes for soundboards are constructed. But the resonance regions were not studied. The conducted analysis of computational and experimental RC has allowed to reveal noticeable differences:

- Uniformity (smoothness) of a computational RC.
- The contents of accessory (“acute”) peaks on the experimental curve.

Probably, such difference is caused by the fact that the computational model of a soundboard doesn't take into account influence of acoustic internal cavity, which has own rigid and an own set of resonance frequencies.

For the purpose of an estimation of influencing acoustic internal cavity on response curves of a soundboard a series of padding experiments executed on the basis of digital spectral analysis is conducted.

The experiments were conducted through the special device “Navigator” made on the basis of the personal computer Cassiopeia EG-800. The device is constructed as the mobile device for research of dynamic parameters of designs. The designed software is intended for the analysis of steady oscillations. The research was executed on an acoustic guitar with “menzura” 540 mm. The soundboard is made of three-layers veneer. From the inside the soundboard had three transversally arranged springs (Fig.1). The guitar body was established horizontally on massive test desktop. The piezoelectric sensor AP-98-100 was used for registration of vibration accelerations. The sensor was installed on a surface of the soundboard sequentially in points 1 and 2 through a special pin. The oscillations were excited by pluck of bass or treble strings (Fig.1, b). Further, the bottom was carved from guitar body so that it had minimal influence on the conditions of fastening of a soundboard. Then guitar body was established horizontally to give free circulation of air above and under a soundboard. Thus, influencing acoustic internal cavity was eliminated.

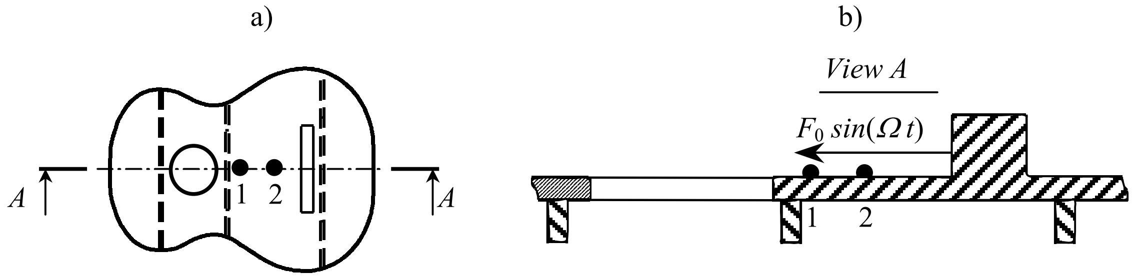


Fig.1. a) Design of the soundboard b) Scheme of the oscillation excitation

Observed data became a set of time-digital sequences of vibration accelerations: $a = f\,[n]$ (Fig.2). In instants t_0, t_1, t_2, …, $t_{N\text{-}1}$ were fixed N of discrete values of vibration accelerations. In each point up to five repeated measurements were made.

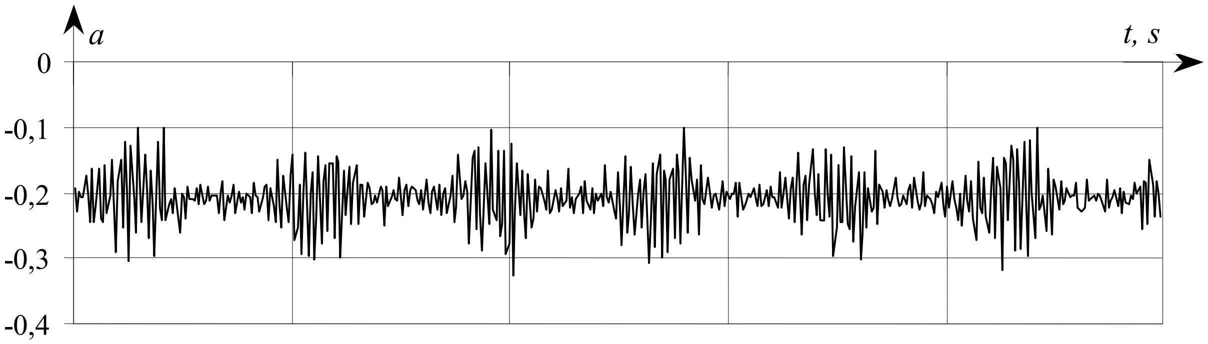


Fig.2. Temporary implementation of a signal

Sampling period $h = \frac{T}{N}$ = 125 mcs, where T - fundamental period of oscillations. Frequency $f_h = \frac{1}{h}$ = 8 kHz is a cut-off frequency, or Nyquist rate. According to Nyquist theorem the best spectral component of a signal receives in 2 times less, that is in the range up to 4 kHz the construction of a spectrum is possible.

Relation $a = f\,[n] = f\,(nh)$ was twice integrated. In this case the program MathCAD 2000 was used. The obtained discrete amplitude-time sequence $w\,[n]$ subjected to numerical Fourier transforms:

$$W[f] = h\sum_{n=0}^{N-1} w[n]\exp\left(\frac{-i2\pi fn}{N}\right), \tag{1}$$

$w[n] = w(nh)$.

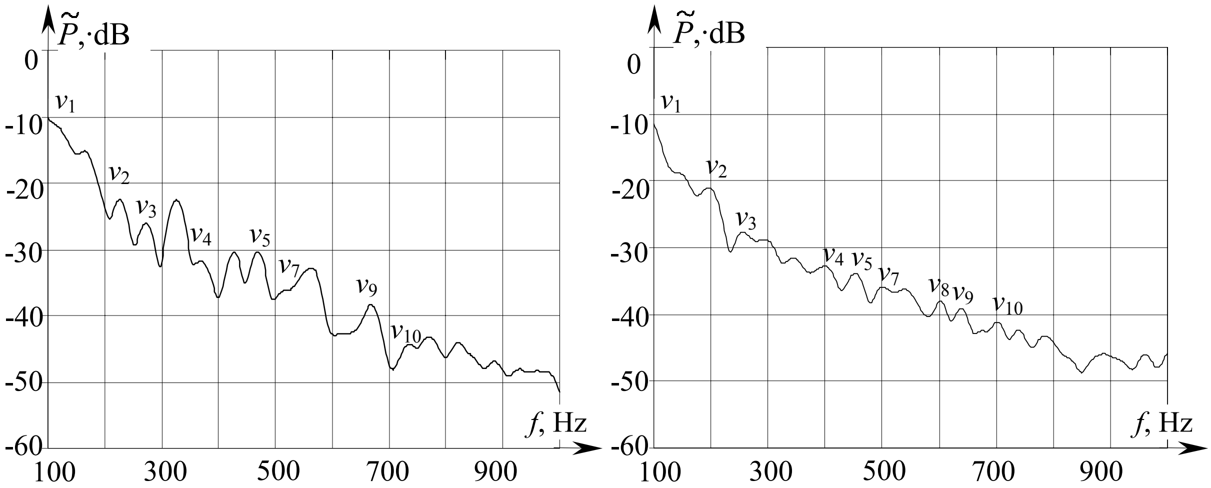
Here $w\,[n]$, (n = 0, 1, … N - 1) – off-on signal, $i = \sqrt{-1}$. Then the spectral concentration of power (SCP) was determined) [3]:

$$P(f) = \frac{h}{N}\left|\sum_{n=0}^{N-1} w[n]\exp\left(\frac{-i2\pi fn}{N}\right)\right|^2. \tag{2}$$

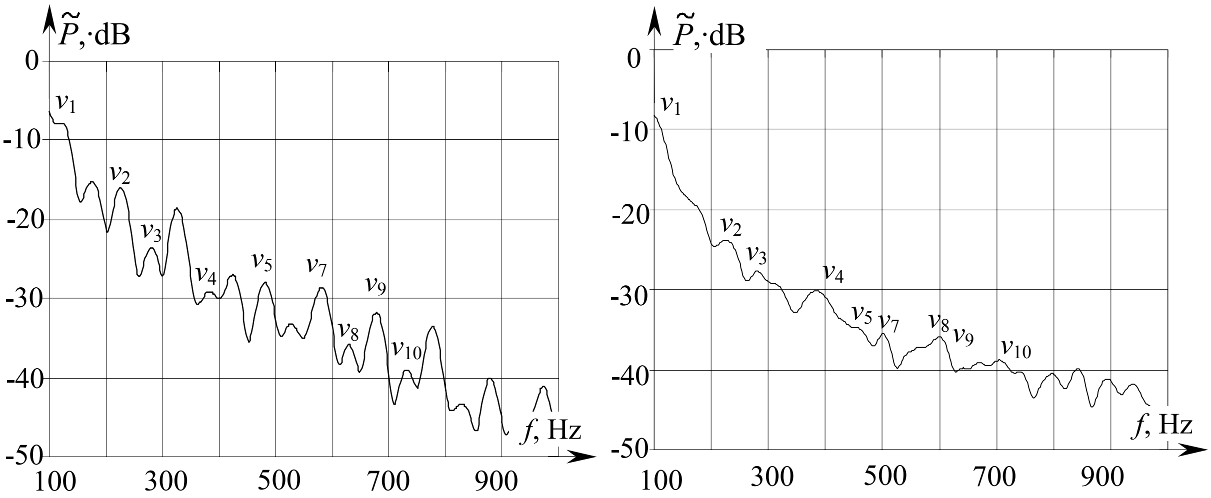
It is known, that the elective spectrum gives statistically inconsistent estimators of SCP. As a rule, the false peaks take place, which locations change depending on the coordinate of a time zero. One of the most effective smoothing methods e.g. Whalch method in this connection was used [3].

The data $w\,[n]$ were broken on K of segments on D of readouts in each with shift S between adjacent segments ($S \leq D$). The maximum number of segments K was determined by the whole part of number $K = (N\text{-}D)\,/S\text{+}1$. Each segment as "weighted" by means of Nuttall window. The averaging on the periodograms of segments gave a final estimation of SCP:

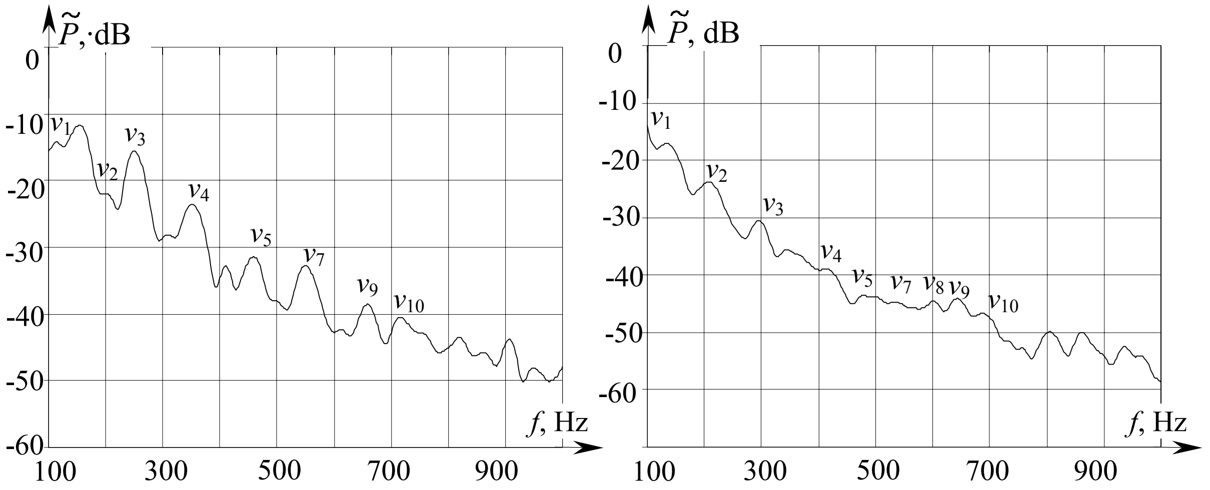
Soundboard with a resonator Soundboard without a resonator



Measurement in the point 1



Measurement in the point 1



Measurement in the point 2

Рис.3 Periodogram estimation of SCP

$$P(f)=\frac{1}{K}\sum_{k=0}^{K-1}P^k(f). \tag{3}$$

For a graphical representation of results the logarithmic scale was used. On an ordinate axis the difference of levels of SCP in dB was sidetracked:

$$\widetilde{P}(f)=10Lg\left(\frac{P(f)}{\max(P(f))}\right). \tag{4}$$

In a Fig.3 spectral curves of a soundboard with a resonator, on the right - soundboard without a resonator at the left are submitted. On reference spikes ten lowest eigenfrequencies were determined. The outcomes of experiments are tabulated. Predicted data are submitted below.

Eigenfrequencies, Hz	Experiment		Computation
	Soundboard with a resonator	Soundboard without a resonator	
ν_1	120 – 136	110 – 120	112
ν_2	210 – 230	200 – 215	210
ν_3	260 – 280	260 – 280	271
ν_4	320 – 335	340 – 355	375
ν_5	435 – 460	430 – 460	454
ν_6	496 – 500	485 – 500	500
ν_7	525 – 535	510 – 540	512
ν_8	580 – 595	600 – 610	611
ν_9	620 – 630	615 – 625	615
ν_{10}	720 – 740	710 – 720	743

It follows from the comparative analysis of results:

- The spectral curve of a soundboard with a resonator contains padding peaks – acoustic resonances on frequencies of 150-170 Hz, 310-320 Hz, 400-410 Hz. The peaks have brightly expressed nature.
- The eigenfrequencies of a soundboard with a resonator and a soundboard without a resonator differ from each other a little.
- In general the eigenfrequencies established experimentally match the calculation quite well.
- The spectral curve of a soundboard without a resonator is formed being straighter on a structure of amplitudes, than soundboard with a resonator. Apparently, the resonator increases a radiation energy of a note in the field of eigenfrequencies of soundboard oscillations.

REFERENCES

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