Harmonic and unharmonic components of violin tones in relation to playing techniques

Ondřej Moravec, Jan Štěpánek, Václav Syrový

Music Faculty, Academy of Performing Arts in Prague,
Malostranské nám. 13, 118 00 Praha 1, CZECH REPUBLIC,
E-mail: MORAVEC@H.AMU.CZ

Summary: Properties of harmonic and unharmonic spectral components of violin tones played nonvibrato using different bowing techniques (*naturale*, *sul ponticello*, *sul tasto*) and playing dynamics (*p*, *mf*, *f*) were studied. Tones from the whole violin range were recorded in an anechoic room. The spectral envelope shape, and amplitude relations among harmonic components were observed. The dependence of the spectrum on playing technique, dynamic and tone pitch were discussed.

INTRODUCTION

The results published in this paper are part of a research project, whose final result will be the taxonomy of signals of musical instruments used in a symphony orchestra. The results from the analysis of signals produced by a violin played in an anechoic room are given. The recording method is described in (1), the analysis results of signal time properties are presented in (2). This paper deals with the properties of the spectra of signals quasistationary parts.

METHOD

In an anechoic room violin tones were recorded played *sul tasto*, *naturale* and *sul ponticello,* in dynamics *p*, *mf* and *f* by a professional violinist on an instrument made by François Gande in Paris, 1825. To investigate the directivity of violin radiation (1) simultaneous recordings were made using 16 microphones located in a circle with a diameter of 1.6 m, with the instrument located in the center. Recordings made in the direction labeled „0°“ were selected for the investigation of spectral properties.

The analysed tones: G_3, D_4, A_4, E_5 (open strings),
H_3, $F\#_4$,$C\#_5$, $G\#_5$ (fingered strings).

For each tone sample the amplitude of harmonics in the frequency band 0 ÷ 8 kHz were calculated from the quasistationary part of the signal. The spectral center of gravity (FCG) was then calculated. Considering inharmonicity, the FCG is defined as follows:

$$FCG = \frac{\sum_{k=1}^{n} f_k A_k}{\sum_{k=1}^{n} A_k} \quad [\text{Hz}]$$

where:

- n number of harmonics in spectrum,
- f_k frequency of k-th harmonic (in Hz),
- A_k linear amplitude of k-th harmonic (in V).

The upper boundarys of analysed band was chosen as a compromise between different spectral lengths of low and high pitched tones. The results of (3) were also considered.

RESULTS AND DISCUSSION

The slope of the spectral envelope (up to 8 kHz) does not change with regard to playing technique or dynamic. The tones played *naturale* show the best repeatability. When the dynamic is changed, the spectral envelope of tones played on fingered strings shows smaller changes than that of tones played on open strings. As shown in TABLE 1, the spectrum of tones played *naturale* widens with increasing dynamic, but it cannot be said for cases of *sul tasto* and *sul ponticello*. The spectrum also widens with changes in bowing technique from *sul tasto* to *naturale* to *sul ponticello*.

TABLE 1. Length of the harmonic part of the tone spectrum for different dynamics and playing techniques.

		sul tasto	naturale	sul ponticello
G_3	*p*	6	6	8.7
	mf	6.5	11	11
	f	10	13	10
D_4	*p*	10	12.5	15
	mf	12	17	18
	f	15	18	20
A_4	*p*	15	19.5	21
	mf	20	22	22
	f	20	21	22
E_5	*p*	20	22	22
	mf	22	22	22
	f	22	22	22

FIGURE 1 shows increasing levels for all harmonics in the band up to 8 kHz when the dynamic is increased from *p* to *f*. Changes in the spectral center of gravity presented in FIGURE 2 indicate that the levels of the higher harmonics for tones played *naturale* increase slightly more than the levels of the lower harmonics. High values of FCG for tone E_5 indicate that spectrum of that tone is much richer in high harmonics than the spectra of the other three tones.

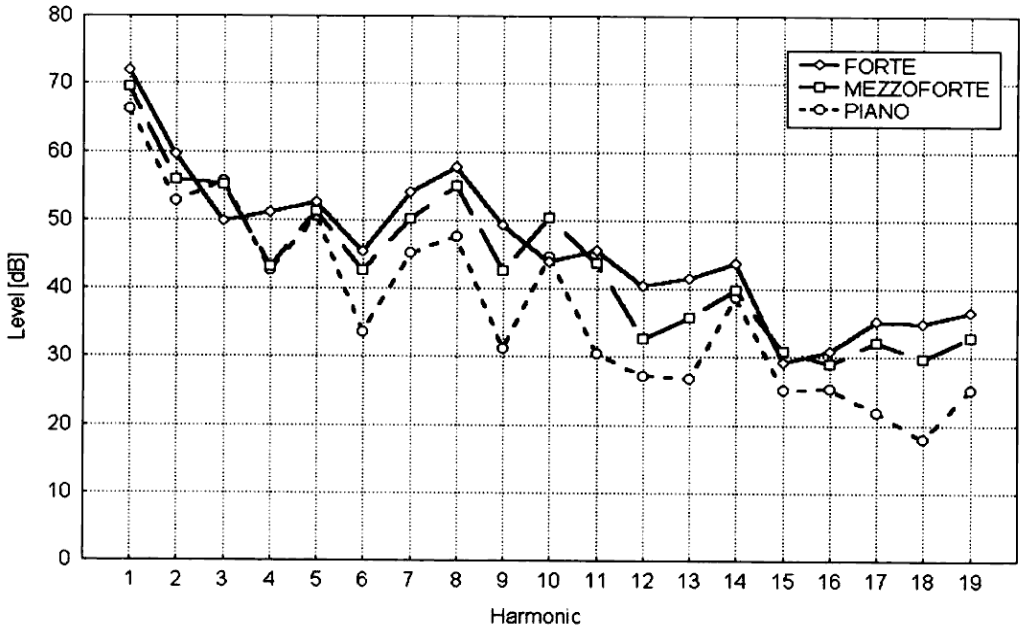

FIGURE 1. Harmonic spectra of the violin tone A_4 played *naturale* with different dynamics.

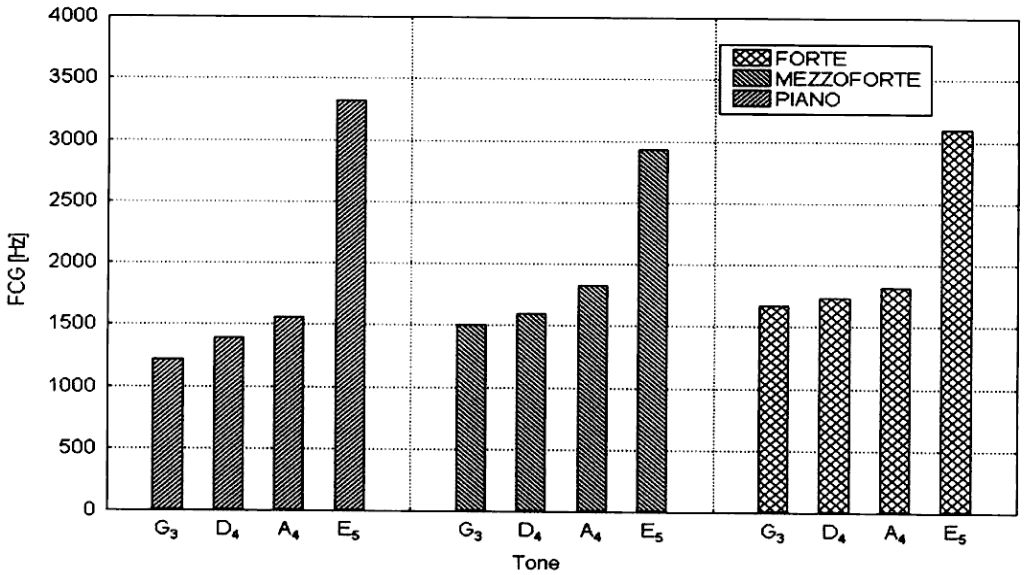

FIGURE 2. Spectral center of gravity of violin tones played *naturale* with different dynamics.

ACKNOWLEDGMENTS

The investigation was supported by the Ministry of Education and Youth (Project No. VS 96031). The violin was played by J. Tomášek, Professor of the Music Faculty of the Academy of Performing Arts (HAMU) in Prague.

REFERENCES

(1) OTČENÁŠEK, Z., SYROVÝ, V., "Directivity of Violin Radiation", in *this proceedings.*

(2) VOLNÝ, P., ŠTĚPÁNEK, J., SYROVÝ, V., "Time Relations Between Harmonics of Violin Tones in Relation to Playing Techniques", in *this proceedings.*

(3) ŠTĚPÁNEK, J., OTČENÁŠEK, Z., SYROVÝ, V., MELKA, A., "Violin Tones Spectra and their Relationship to Perceived Sound Quality", in *Proceedings Institute of Acoustics ISMA'97*, Edinburgh, UK, pp. 125-130, 1997.