SPECTRAL CHARACTERISTICS OF CZECH BAROQUE PIPE ORGANS

Václav Syrový, Zdeněk Otčenášek, Jan Štěpánek

Sound Studio of the Faculty of Music, Academy of Performing Arts Prague,
Malostranské nám. 13, 11800 Praha 1, Czech Republic,
e-mail: syrovy@hamu.cz

Abstract

The method for acoustic documentation of pipe organs developed in the early nineties' was applied to a set of Czech Baroque organs. The documentation method includes recording steady state sounds of all organ stops and plena, room acoustic measurement and diagnostic methods. Diapason stops constitute the plenum of an instrument, whose sound is the most representative for each organ. Examples of spectral analyses of recordings of diapason and plenum steady-state sounds of twelve Baroque instruments are presented. The Factor Analysis method was used to construct of multidimensional spectral spaces representing plenum sound in C2 – C5 octaves. The main differences in Baroque instruments are revealed in levels of the highest harmonics and of the first harmonic of the spectrum. Reconstructed instruments have stronger levels of higher harmonics arising from restored Mixtur stops.

INTRODUCTION

The organ as a musical instrument has many specific acoustic and technical properties. Its sound richness is determined by the complexity of its technical construction. Both the organ's general sound design and diversity in creating individual sounds, together with its construction, have undergone long historical development, especially in the Gothic, Renaissance, Baroque and Romantic periods in diverse European countries and regions. Several organ types emerged, differing in specification of stops, instrument range, and absence of specific tones. The interpretation of existing musical pieces is often closely linked to instruments originating in a specific time or place. Moreover, every instrument is firmly connected with the space in which it is found, thus becoming an acoustically original musical instrument.

The Czech organ builders indisputably reach the zenith of organ sound richness and beauty in the Baroque period. An entire range of instruments was preserved from this period, modified to a greater or lesser extent in the past. In recent years, greater attention has been paid to rare historical organs. These instruments are gradually reconstructed or restored, preserving or resetting original specification and use of original pipes. Part of the effort to preserve rare instruments is acoustic documentation of their sounds.

CHARACTERISTICS OF THE DESCRIBED INSTRUMENTS

The method for acoustic documentation of pipe organs developed in 1991 – 92 [1] was used also on a set of twelve Baroque instruments found in Gothic and Baroque churches. Coincidentally, the documented instruments were least affected during the earlier changes in the first manual (Great organ); for this reason it is the sole object of our study. Some characteristics of the studied set of organs are found in Table 1, data on where they are situated is indicated in Table 2. Originally, Czech Baroque organs had range of four octaves (C2 – C5) and were characterised by a short C2 octave, which contained only the tones C2, D2, E2, F2, G2, bB2 and B2. Four instruments were chromatised during the earlier changes; their current state and other instrument characteristics are found in Table 3. Table 4 indicates Great Organ plenum composition. Diapasons (Principals) of Czech Baroque organs are formed most frequently by the Principal 8', Oktave 4' and Superoktave 2' and very often by Quinte 2 2/3' (ten of twelve instruments). The row of the stop length of 1 1/3' (in Quinte or Mixtur) is also present in nine instruments. The octave and quint rows also dominate in Mixturs, which have repetitions during the range.

Table 1. List of documented Baroque organs.

place	church	builder	year	code
Praha	P. Marie před Týnem	H. H. Mundt	1673	TYN, TY2(*)
Český Krumlov	U P. Marie	N. Christeindel	1682	KRU
Český Krumlov	sv. Vít	unknown	169?	CKR, CK2(*)
Praha	sv. František	A. Starck	1702	FRA
Polná	Nanebevzetí P. Marie	J. D. Sieber	1702	POL
Žďár n. Sázavou	Nanebevzetí P. Marie	J. D. Sieber	1723	ZDA
Most ([1])	Gothic transferred	V. Starck	1741	MMO
Most ([2])	Gothic transferred	V. Starck	1741	MOS
Praha ([2])	sv. Mikuláš	T. Schwarz	1746	MIL
Dub na Moravě	proboštský chrám	J. Výmola	1769	DUB
Žlutice	sv. Petr a Pavel	F. P. Noli	1775	ZLU
Praha ([1])	sv. Mikuláš	T. Schwarz	1788	MIK, MI2(*)

([1]) small organ, ([2]) main organ, (*) documentation after the last reconstruction.

Table 2. Characteristics of the churches.

code	TYN	KRU	CKR	FRA	POL	ZDA	MMO	MOS	MIL	DUB	ZLU	MIK
church	G	G	G	B	B	G	G	G	B	B	G	B
volume [m^3]	20600	3900	11100	8500	11900	12000	17500	17500	29000	14100	–	29000
T_{500} [s]	5.2	2.5	4.3	6.6	3.3	3.7	6.1	6.1	7.3	6.0	2.0	7.3

church: G – Gothic, B – Baroque; T_{500}: reverberation time in the 500 Hz third-octave band.

Table 3. Great Organ characteristics.

code	TYN	KRU	CKR	FRA	POL	ZDA	MMO	MOS	MIL	DUB	ZLU	MIK
range (tones)	C2–C6	C2–C6	C2–C6	C2–C6	C2–C6	C2–C6	C2–C6	C2–C7	C2–A6	C2–C6	C2–C6	C2–C6
C2 octave	+	+	+	–	+	+	+	–	–	+	–	+
no. of tones	45	45	45	49	45	45	45	61	58	45	49	45
P [Pa]	667/638	539	618/530	765	706	570	500	735	706	589	638	736/834

C2 octave: + short, – chromatic, P: windchest airpressure (before/after the reconstruction).

Table 4. Great Organ plenum composition.

code	TYN	KRU	CKR	FRA	POL	ZDA	MMO	MOS	MIL	DUB	ZLU	MIK
Principal 8'	+	+	+	+	+	+	+ ([1])	+	+	+	+	+
Oktave 4'	+	+	+	+	+	+	+	+	+	+	+	+
Quinte 2 2/3'	+	+	+	+	+	+	+	+		+		+
Superoktave 2'	+	+	+	+	+	+	+	+	+	+	+	+
Quinte 1 1/3	+	+			+		+				+	+
Sedecime 1'	+				+				+			+
Mixtur 2'				VI				VI	VI			
Mixtur 1 1/3'					V	III				VI		IV
Mixtur 1'	VI	IV	IV				III				III	
Cimbel 2/3'	IV				III				IV			

([1]) Coppel Flute 8', the roman numbers in Mixturs denote the number of pipe rows.

METHOD AND RESULTS

The documentation method includes recording steady state sounds of all organ stops and plena, together with c-note transients and room acoustic measurement [1]. The quasi-stationary parts of the tones are recorded by three microphones placed in the typical listening position in a church, three

neighbouring semitones (triads) are played simultaneously [2], and the mean spectrum from three microphone signals is calculated for each triad. The sliding adjustment of the sampling rate to the stop foot length as well as to the fundamental frequency (sliding sample rate) ensures the same discrimination and position of tones in the spectrum of all triads.

Applying the analysis to the recordings, it is possible to separate the harmonics of individual tones in each triad spectrum until the 6^{th} harmonic and calculate their levels. The examples of separated harmonic spectra and their averages over the octave are found in Figure 1. The sound character of the instrument is most expressive in the plenum. The Great Organ plenum of documented instruments consists of octave and quint diapason stops (see Table 4). Thus, in its spectrum the following harmonics dominate: 1, 2, 3, 4, 5, 6, 8, 10, 12, 16, 20, 24, 32, 40, 48, 64, 80, 96. Each of their frequencies fall into different third-octave bands if the band boundaries change according to fundamental frequency [3]. This enables substitution of the levels of harmonics by third-octave band levels. The examples of plenum harmonic spectra and octave averages are found in Figure 2. It is apparent from Figures 1 and 2 that octave averages provide good representation for the spectra in each octave for compared instruments.

The mean harmonic spectra in C2 – C5 octaves from fifteen measurements (twelve before the reconstruction and three after the reconstruction) were used to evaluate a set of documented Baroque organs. It is not possible to compare the power of individual instruments because of different church dimensions. As a result the levels in each harmonic spectrum were normalized on an overall spectrum level. Factor Analysis (FA) – principal components method with varimax rotation – was used separately on each C2 – C5 octave using levels in individual harmonics as variables. Multidimensional spectral space of instruments as objects was constructed from the factor scores, and the main results are found in Table 5. Resulting spectral spaces of two main factors and examples of extremely differing spectra are found in Figure 3.

Table 5. Results of Factor Analysis of Great Organ plena.

octave	analysed levels of harmonics	no. of factors (eigenvalue > 1)	% of variance			harmonics with significant factor loadings (+ positive, – negative)	
			Σ	F1	F2	F1	F2
C2	1 – 96	5	85	35	15	+ from 24 to 96	+ 12, – 1
C3	1 – 64	5	84	34	19	+ from 24 to 64	+ 8, 12, 16, – 1
C4	1 – 32	5	85	27	16	+ from 16 to 32	+ 4, 6, – 1
C5	1 – 16	3	82	45	21	+ from 5 to 16	+ 2, – 1

DISCUSSION AND CONCLUSION

Octave averaging is a concise compression of the properties of an organ spectra envelope. The main differences in levels of the plenum spectral envelope in Baroque instruments remain stable in the entire range (C2 – C5 octaves). Instruments differ mainly in levels of the highest harmonics and of the first harmonic of the spectrum. Reconstructed instruments have stronger levels of higher harmonics (see their right shift along the first factor dimension in Figure 3), rising probably from restored Mixtur stops. But their 'Baroque' sound remains preserved, and they remain in the group of Baroque instruments in all four studied C2 – C5 octaves.

ACKNOWLEDGMENT

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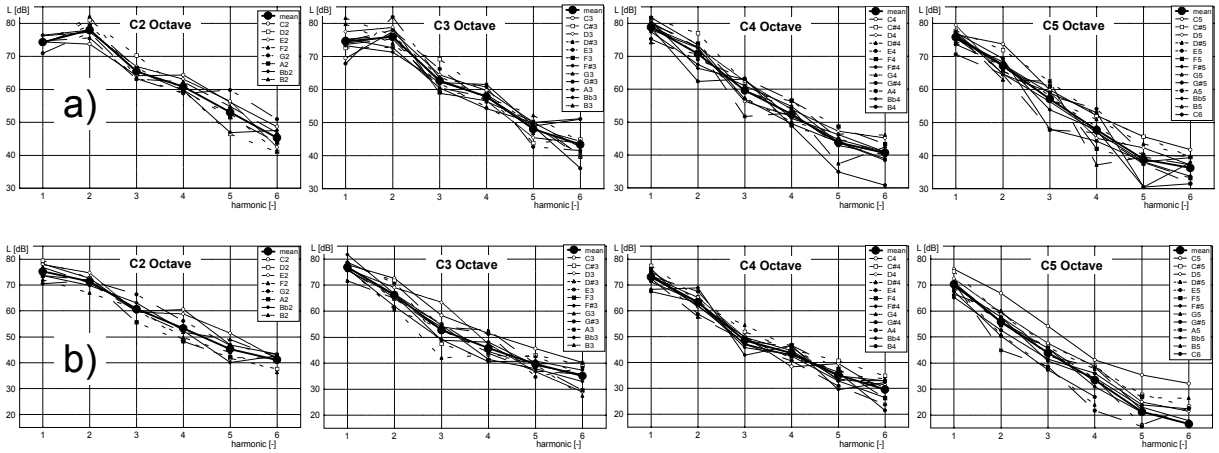

Figure 1. Harmonic spectrum of individual tones in C2 – C5 octaves and mean spectrum in each octave for TY2 instrument and a) Principal 8', b) Oktave 4' stops.

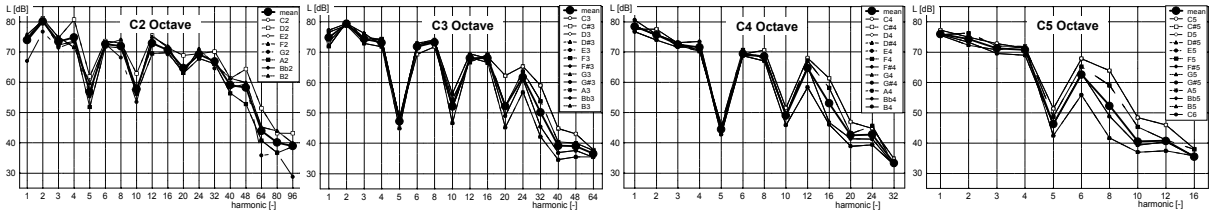

Figure 2. Harmonic spectrum of individual tones in C2 – C5 octaves and mean spectrum in each octave for Great organ plenum of TY2 instrument.

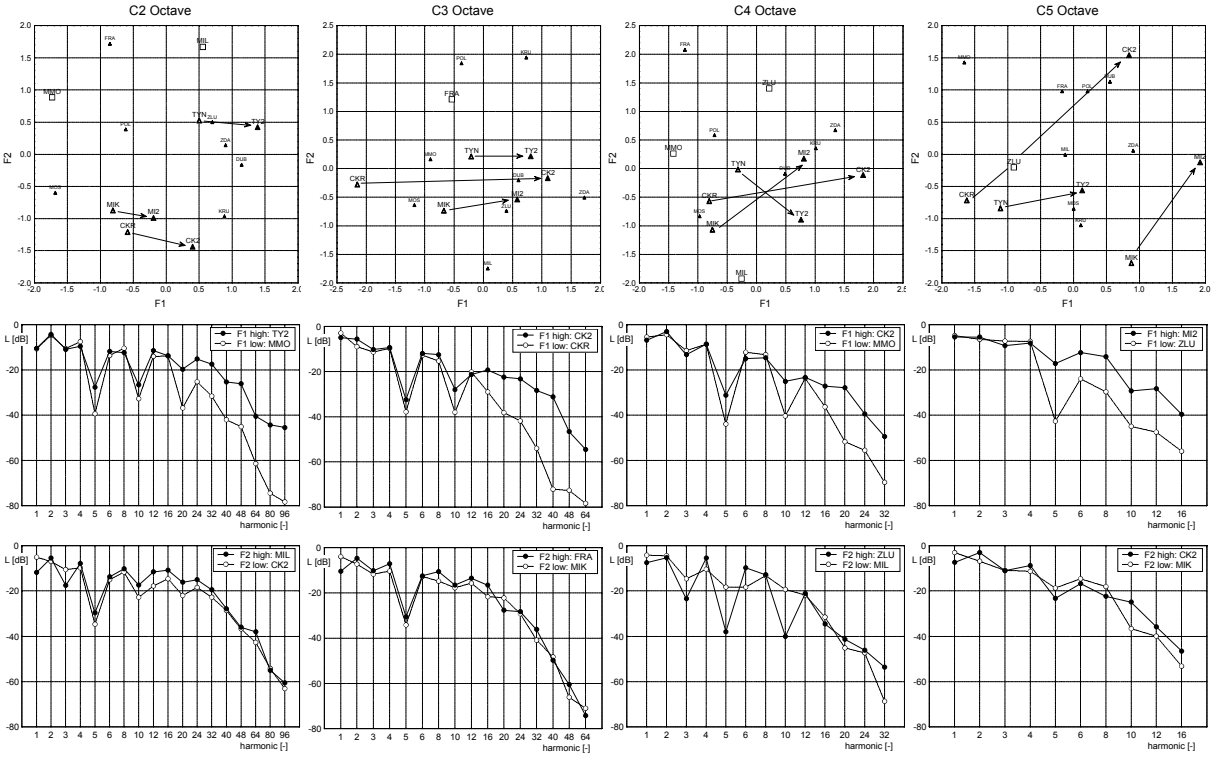

Figure 3. Spectral spaces of Great organ plenum of a set of Czech Baroque organs and examples of harmonic spectra of the instruments differing in the first or second factor scores. The positions of selected instruments and instruments measured before and after the reconstruction are higlighted.