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Active Sound Design of a Bassoon

Frederic Konkel[a], Andre Jakob[a], Frank Heintze[b] and Michael Möser[a]

[a]TU Berlin, Institute of Fluid Mechanics and Engineering Acoustics, Einsteinufer 25, Sekr. TA 7, D-10587 Berlin, Germany
[b]Staatskapelle Berlin, Staatsoper Unter den Linden, Unter den Linden 7, D-10117 Berlin, Germany
kontakt@advacoustics.de

Possibilities of influencing the sound characteristics of a woodwind by means of active noise control were investigated. The woodwind used in this investigation was a bassoon. The first step of the investigation consisted of a set of measurements of the sound spectra of different tones and volumes by means of measurement microphones inside and outside the instrument. Additionally measurements of the radiation characteristics of the instrument were performed by means of the acoustic camera. An experimental setup was designed with the instrument driven mechanically by compressed air. The aim of the work was to change the sound characteristics of the bassoon by changing individual harmonics of the tones by means of a loudspeaker attached to the bassoon. The loudspeaker was attached to the bassoon via a tube. Suitable positions for the connection of the tube to the instrument were examined as well as suitable possibilites for the generation of the reference signal neccessary for the feedforward control scheme. The experimental setup will be presented here as well as results of the measurements with and without active sound design with an analog controller.

1 Introduction

Figure 1 shows the bassoon hung into a stand. The bassoon used consisted of the complete wooden body made of maple, the embouchure, the S-shaped tube and the 180°-direction change at the bottom of the instrument. Solely, the flaps were missing. They were replaced by filling the tone holes with wax or other coverings. For the experiments described here, a constant tone was necessary. The instrument was tuned to the musical note "f" with its fundamental frequency of 174 Hz. For reproducibility it was also necessary to supply the instrument with a constant air-flow to the embouchure. For this task a device was built which very roughly simulates mouth and lips of the instruments player (cf. Figure 2). To provide for enough humidity of the double-reed the air-flow coming from an compressed air source was directed through a tank filled partially with water.

Figure 1: Bassoon in stand.

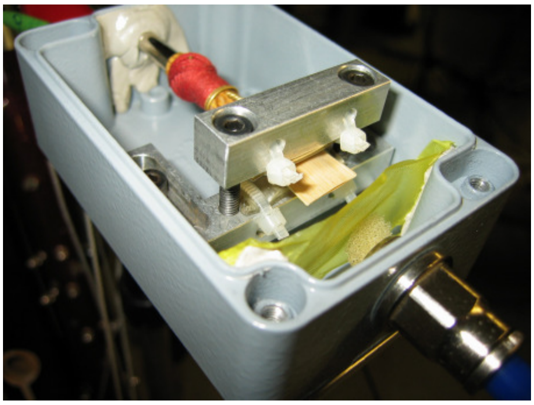

Figure 2: Mouth and lips simulator.

2 Experimental Setup

In the experiments was investigated the general possibility of influencing the sound of the instrument as well as suitable positions for the insertion of the secondary sound signal. It was also found that a suitably reference signal necessary for the generation of the secondary signal could be obtained from an accelerometer attached to the S-tube (cf. Figure 3). It was noted, that with a microphone instead of the accelerometer the active system tend to be more unstable.

An additional microphone in the surrounding room was used to evaluate the success of the active means. From the input signal (acceleration at the S-tube) the fundamental frequency of 174 Hz was extracted by means of a bandpass filter. This signal served as the input signal to an analog controller for the generation of up to 16 harmonics, which could be tuned in magnitude and phase individually (cf. Figure 4).

The generated secondary sound signal was radiated into the bassoon via a loudspeaker and a long tube. Thus, the loudspeaker could be placed away from the instrument and did not influence the measurements outside the instrument.

Figure 3: Accelerometer attached to the S-tube.

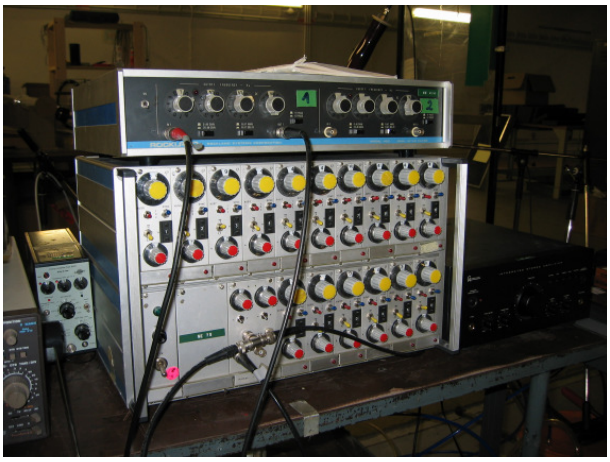

Figure 4: Analog controller ("harmonics generator").

3 Positions of Sound Insertion

Several positions for the insertion of the secondary sound were investigated, i.e. an unused tone hole (cf. Figure 5), the open end of the bassoon and the 180°-direction change at the bottom of the instrument.

For the sound insertion at the 180°-direction change at the bottom of the instrument a new 180°-tube was built with a junction for the loudspeakers tube (cf. Figure 6).

The sound radiation of the instrument was measured via the microphone in the room and evaluated by means of narrow band spectra (FFT). The position found to be most effective for the insertion of the secondary sound in terms of variability of the resulting instrument sound and in terms of stability of the active system was the 180°-direction change at the bottom of the instrument.

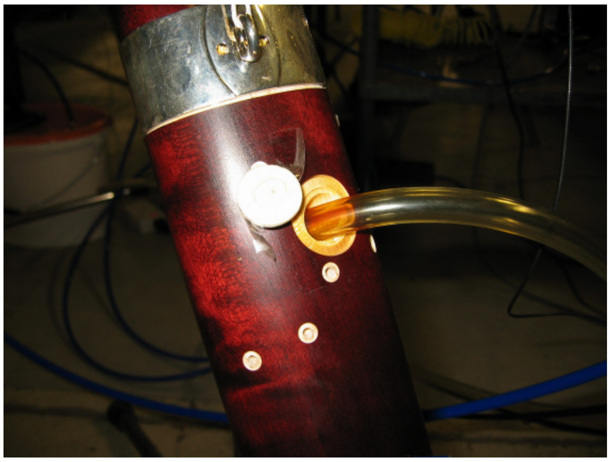

Figure 5: Insertion of secondary sound through unused tone hole.

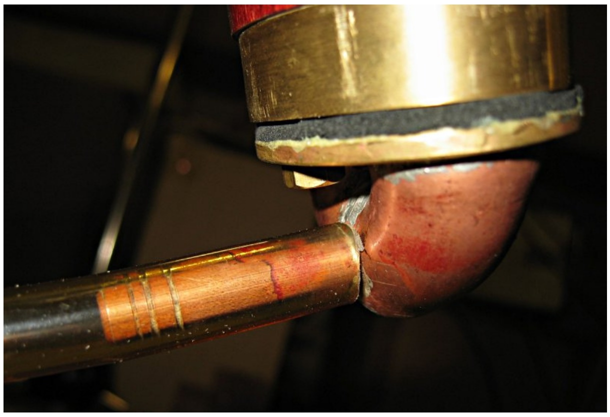

Figure 6: Insertion of secondary sound at 180°-direction change.

4 Results

In Figures 7 and 8 are given sound spectra of the 174 Hz tone without (black curves) and with active control (red curve). All spectra shown are A-weighted.

The spectra in Figure 7 resulted from controlling the fundamental frequency only. But, it was observed that simultaneously harmonics of the fundamental frequency were changed, too. This can be explained by the non-linear coupling of the acoustics modes inside the instrument ("regime of oscillation" [1]). Here the influence of lower modes on higher modes was found to be higher than the influence of higher modes on lower modes. The influence on the resulting sound did not only depend on the magnitude of the secondary sound but also on its phase. The difference between the results given in Figure 7 was mainly due to the large phase difference of the secondary sound signals.

In Figure 7 (top) the fundamental frequency was amplified by approximately 15 dB. At the same time the second mode was amplified by 2 dB whereas the third mode was reduced by 10 dB. At higher modes mainly a reduction of the harmonics was observed. The sound characteristic was felt to be "flannelly" and, of course, appeared to contain more of the fundamental frequency than without active control.

In Figure 7 (bottom) a different result is shown. Some harmonics were amplified, some were reduced. Again, the fundamental frequency dominated the sound characteristic, but the tone appeared to be somewhat more "brilliant".

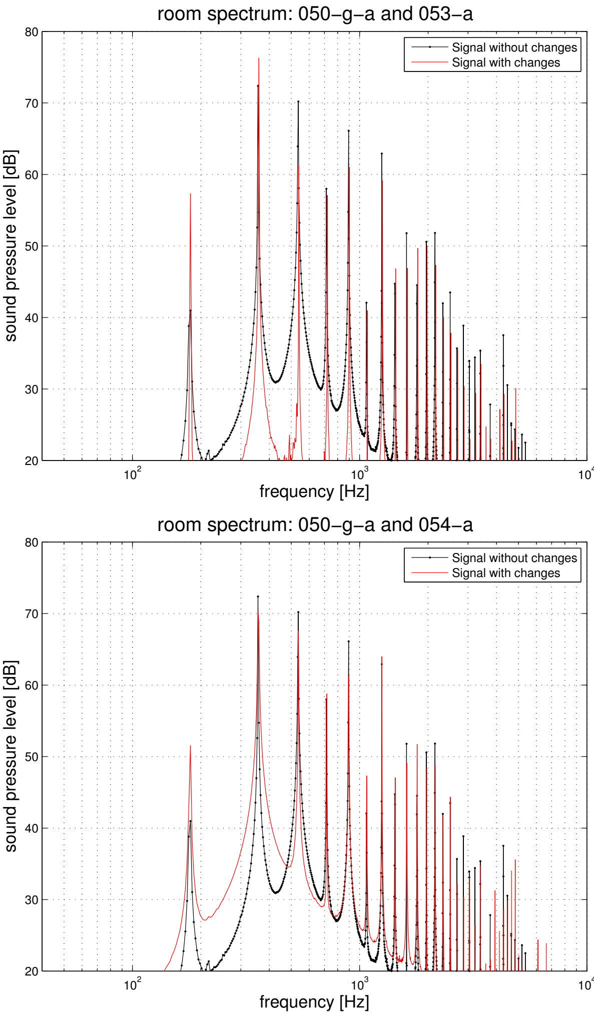

Figure 7: Examples of change of sound for the control of the fundamental frequency only.

Figure 8 shows, that even more complex sound variations are possible, if more modes are controlled simultaneously. The sound shown in the upper diagram resulted by controlling the modes 1 to 5 and 12 to 14. High amplification of the fundamental frequency and some amplification of the second mode can be seen. The third mode and some of the following modes were reduced. The range from 1 kHz to 6 kHz was not changed very much at all. The sound characteristic showed a strong fundamental component but appeared also to be "brilliant". In contrast to this sound the characteristic of the lower spectra in Figure 8 showed remarkably level reductions of a lot of higher harmonics. The first 10 modes were controlled. The result was a sound which appeared very "calm" and "gentle".

5 Concluding Remarks

Generally, it was found that active amplification of harmonics is much easier than active reduction of harmonics. This, of course, is a platitude, and well-known in active noise control. The effort in accuracy is much higher for reductions than for amplifications. This is of importance for potential automatic control schemes, because the control of one mode always influences a number of other modes simultaneously.

References

[1] Benade, Arthur H.: Fundamentals of Musical Acoustics, Dover Publications, Inc., 1990

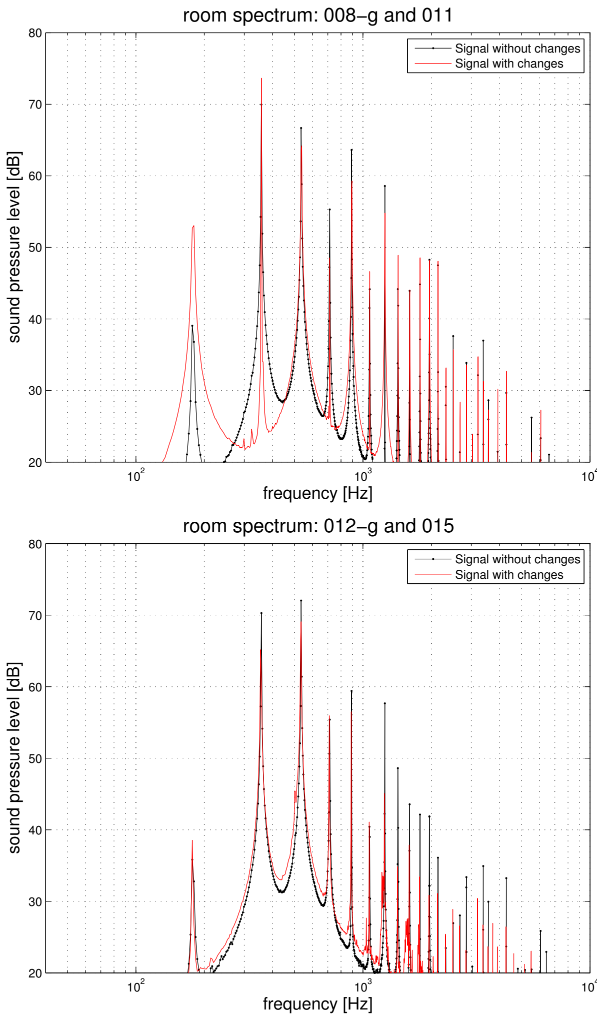

Figure 8: Examples of change of sound for the control of the fundamental frequency and several harmonics simultaneously.