Sound radiation of double reed woodwinds

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Introduction

The analysed double reed instrument in this investigation is the bassoon. This tests are crucial for the active sound design of a bassoon to locate the best position for the active influence [1].
Sound radiation is the ratio between the sound pressure radiated by the instrument to the sound pressure inside the instrument. Hence, one hundred percent sound radiation is a full release of the instrument.
In the recent past the verification of the radiation properties of woodwinds was measured by using microphones next to the woodwind holes. Hence, it was of particular importance to use suitable microphone positions between the woodwind holes and free space. In the present contribution the radiation properties of the woodwind holes and the bell of a bassoon are investigated by using an acoustic camera (GFaI e.V.) [2].
The analytical description of a double reed woodwind is nonlinear [3]. When analysing a bassoon it has to be taken into account that the pipe is conical with different kinds of open and closed tone holes.

Technical assembly & instrumentation

A typical position to play the bassoon is chosen. To take a picture of the sound radiation the camera is located in one of three positions (left hand side, in front of and right hand side).
The acoustic camera used is the "Array-Ring 32-75" [2]. It is feasible to measure in a distance range of 0.7m to 3m for frequencies up to 1 kHz. The frequency range of the camera is between 300 Hz and 20 kHz.

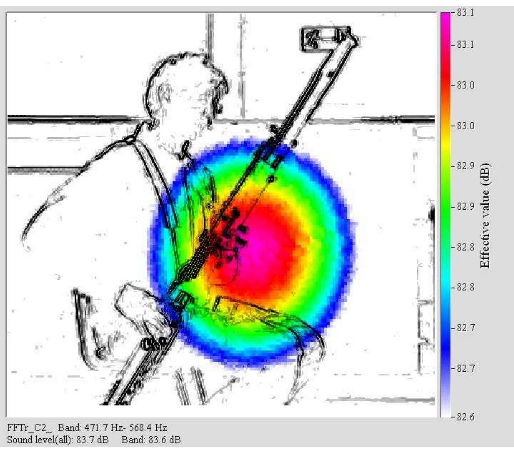

Figure 1: C5 first mode with $f = 523.3$ Hz

The frequency range of a bassoon is between 58 Hz and 5.5 kHz. The distance used for the investigation of the

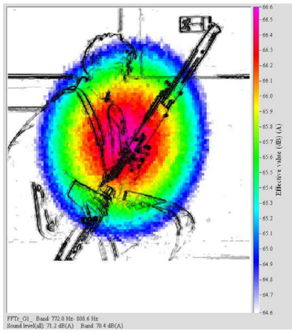

Figure 2: G4 2nd mode (784 Hz)

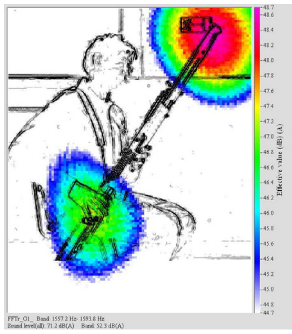

Figure 3: G4 4th mode (1568 Hz)

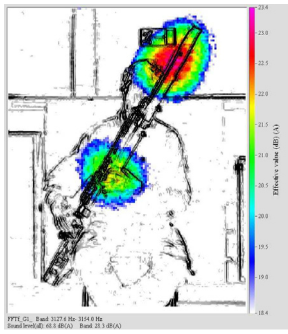

Figure 4: G4 8th mode (3136 Hz)

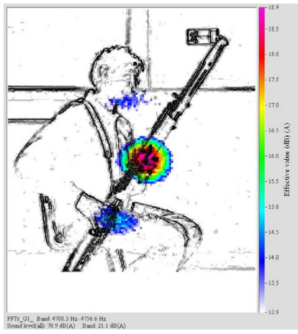

Figure 5: G4 12th mode (4714 Hz)

sound radiation of the whole bassoon is 2.44 m. Therefore, the measured data are significant above 500 Hz. The positioning of the focused camera layer is chosen by the spatial position of the bassoon. The averaged FFT time is set to 4 s. Ten notes are measured between C2 and C5. All notes are played in mezzo forte. The total sound levels are between 70 dB and 80 dB.
For a mathematical analysis the size of the bassoon is divided into ten parts from the bottom (boot joint = 0) up to the top (bell = 10) (for instance compare figure 1 and the y axis of figure 6). The first mode of the note G4 is not displayed because in this frequency range only diffraction is visible. The first mode at 523.3 Hz for tone C5 is displayed. Naturally, the position of the sound radiation can only change while there are some open holes, as given by higher notes.

Familiar theory & new identified ranges

The well known cutoff frequency ("The Open-Hole Lattice Cutoff Frequency") range can be noticed in the given analysis. The cutoff frequency of a bassoon is in the range between 350 Hz and 500 Hz. [4] [5]

In figure 2 to figure 5 the sound radiation of different modes for the note G4 is graphically displayed. It is obvious that the sound radiation of the different modes changes with frequency. Hence, it can be observed that the sound radiation changes with the cutoff frequency. But as can be seen in the pictures there are more radiation phenomena.

In the first noticeable range the sound is radiated by two parts of the bassoon. The more powerful radiation point is located at the bell (see for instance figure 3). Here, this new range is called dual radiation range (see figure 7) and it is located between 1100 Hz and 3300 Hz.

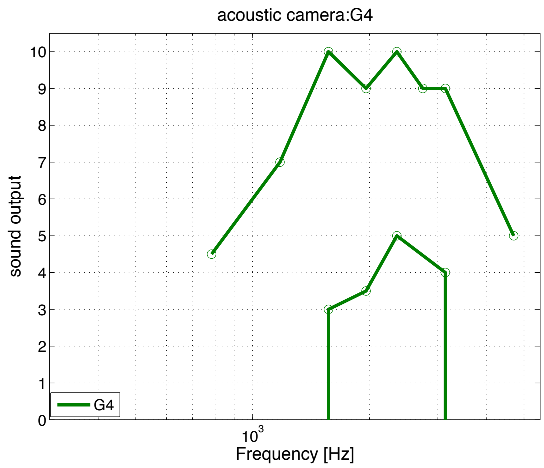

Figure 6: Graphical analysis of the sound radiation of the tone G4

In the second new identified range the sound radiation runs from the bell to the last open tone hole. This effect is observable for frequencies over 3300 Hz. Here, this range is called cut down range (see range 3 in figure 8). For frequencies above this frequency the position of the sound radiation does not change. Obviously, the amplitudes of this high frequencies radiations are low (compare to the fundamental frequencies of the bassoon).

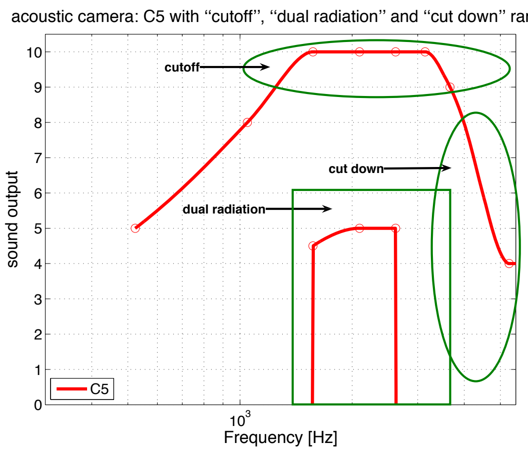

Figure 7: Graphical analysis of the sound radiation of the tone C5

Conclusion

For the acoustic testing the instrument was observed from three directions. The examination of the results verify the known cutoff frequency of woodwinds at medium frequencies. From the experimental investigation, two distinct new frequency ranges are found for the radiation properties of the bassoon.

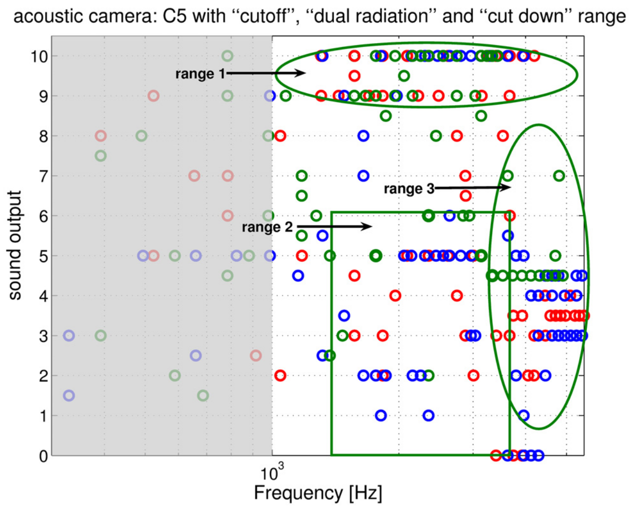

Figure 8: All measurements and all ranges

The first located range between the medium and the high frequencies of the bassoon modes shows that the central radiation is emitted by the bell, but the last open woodwind holes are also a part of the sound radiation. The second noticed range is located at high frequencies and it becomes clear that the sound radiation is only emitted by the last open holes. However, there is no sound radiation by the bell at these frequencies.

References

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