sound by the wall oscillation can take place in principle in two kinds, via energy withdrawal and own radiation via the vibrating walls. It follows a further question immediately: How does the player notice the changes, over the ear or over the sense of touch? How does he evaluate this observation? Does it connect violent wall oscillations, which it feels with the hands, with a good sound? Over many years only small attention was given to these questions.

2. SOUND POWER OF THE WALL OSCILLATION

The sound power of blown tones was measured in anechoic chamber of the IfM. A recording of the vibratory levels at the four points took place. In a second attempt the wall became so lively over a shaker with the noted oscillation signal that the vibratory levels at the four points failed as when blowing on, i.e. approximately same wall oscillations predominated. The sound power radiated now from the wall could be measured in such a way. The following results showed up:

- typical sound power trumpet ***mf***: 102 dB (lin.)
- typical sound power trumpet wall: 56 dB (lin.)
- typical sound power tuba blown ***mf***: 105 dB (lin.)
- typical sound power tuba wall: 56 dB (lin.).

One can state in the result of the measurements that the sound power radiated from the wall is smaller more as 45 dB than „the airborne sound achievement“. It can be excluded with the fact that listeners hear wall sound portions.

3. TO THE INFLUENCE OF THE WALL MODES

At a trumpet and a tuba modal analyses were made and afterwards the spectra of operating oscillations of the wall when single tone alluding were determined. Figure 2 shows the appropriate grid network model of a tuba.

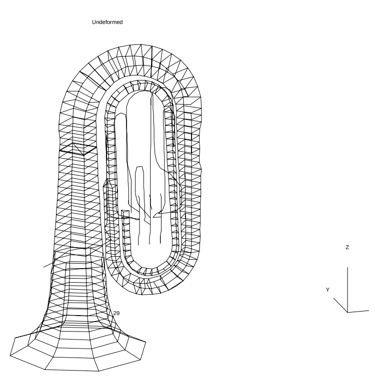

Figure 2: Grid network model tuba for modal analysis

At the following four points at the instrument were the acceleration adaptors: ·

- bell (29) ·
- in the middle of sheet of piece of sound (177)
- lower surface second valve (199)
- mouthpiece ferrule (266)

The numbers mark the points in the grid network model.

Figure 3 shows now the spectra of the operating oscillations of a trumpet, playing tone b. The broken vertical lines mark the frequencies of the found wall fashions. The modal analysis took place up to a frequency of 2 kHz.

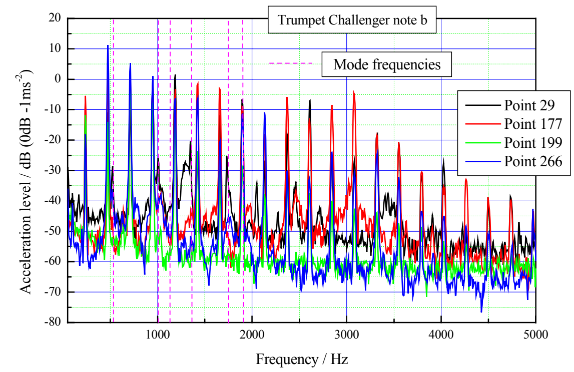

Figure 3: Vibration spectra of different points of instrument

The vibration spectra show that effects of wall self-fashions are provable at the bell only. One recognizes clearly the strongly minted partial tone row of the played tone. The instrument wall implements thus pronounced from the oscillations of the air column lively (forced) oscillations. The amplitude distribution is clearly different than with the modes. Practical all parts of the instrument are almost equivalently (equivalent violently) involved in the oscillations. One finds oscillation portions of the modes as to be expected only on the bell and in small measure on the sheet of piece of sound. The modes will sound by the initial impulse lively and rapidly off. A connection between the characteristics of the determined fashions and the development of the forced oscillations did not let itself manufacture.

4. ACOUSTIC MEASUREMENTS AT THE PLAYER EAR

Due to the radiation characteristic listeners and players notice typically different sounds of the instruments. In the instrumentation sense we understand a position in 1 m distance of the player (2 m with tubes) in typical direction of the spectators by listeners. Records made in the anechoic chamber of the IfM were observed in the context of our measurements again. Beside the microphone in the listener position (see above) a second microphone was positioned at the right ear of the player. The musicians blew single tones of the basic nature tone row. The two microphone signals were noted first on DAT and of afterwards different analyses were submitted. The recording of the two microphone signals secures that in each case at both microphone positions really the same allude one evaluates. In order to be able to separate the effect wall radiations better, a part of the photographs with completely instruments included by foam material took place.

The analyses did not show references on sound portions of the wall. The sound spectra with and without foam material packing were practically identical both at the listener and at the player ear microphone. However, clear differences between listener and player perspective are shown, in particular in the case of trumpet (Figure 4). The averaged spectrum in Figure 4 means the averaging over all in the context of this attempt row made trumpet-records. One recognizes, which the sound pressure level drops clearly above 1500 cycles per second at the player ear. A cause is the arranged radiation of the acoustic horn with higher frequencies. The player hears thus his instrument clearly less brightly, sharply and brilliantly than a listener. With tubes the effect is pronounced clearly less. On the one hand the position of the player ear is to the acoustic horn another, on the other hand arises with tubes more substantial sound portions in deeper frequency ranges.

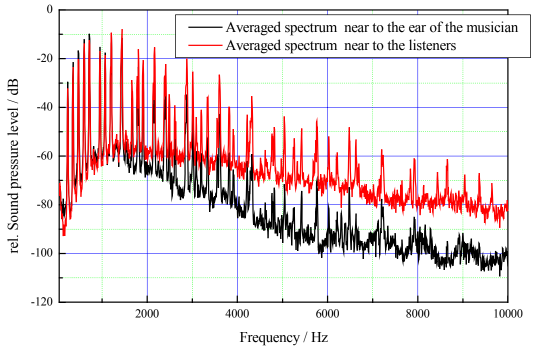

Figure 4: Comparison of the average sound pressure spectra of trumpets at the player ear and at the listeners

5. ENERGY DISTRIBUTION

If thus neither players nor listeners can notice wall sound, from where then again and again the descriptive wall influence comes? We want to compare in addition in the sound and in the wall oscillation putting energies, which must be applied both by the player. The measured sound power levels of 100… 105 dB correspond to an achievement in the SI system of 0,01 Nms^{-1} ... 0,032 Nms^{-1}. For the determination of the energy of the wall oscillation we repeated the attempt described above for the excitation of a play-equivalent operating oscillation by means of shaker. However now at the shaker both the produced oscillation and applied force were noted over an impedance measuring head.

Figure 5: Arrangement to the simulation of the operating oscillations without airborne sound

From the measured values for force and speed of oscillation one can compute the fed, thus achievement necessary for the maintenance of the wall oscillation. The evaluation supplies for trumpets 0.0001 … 0.0006 Nms^{-1} and for tubas 0.0001 … 0.002 Nms^{-1}. I.e. between 1 % and 20 % of the achievement which is in the instrument sound migrate into the wall oscillation. This effect means an additional effort for the musician to create the sound and it is observed by him. During the measured achievement it concerns an active power. It must be applied in the stationary part of the tone permanently around the wall oscillation to keep upright. By friction and in smaller measure by radiation permanently energy is removed from the wall oscillation. However, there has to be another achievement: to generate the wall vibration. Since one gets this achievement back at the end of the tone purely physically, it concerns a reactive power here. The musician cannot use this returned achievement however. It must again apply it with each tone, which in particular with fast passages of short tones of importance can be. An accurate determination of this reactive power was not possible us. We measured it therefore on the basis the measured middle peak-to-peak swings on the instrument wall and the instrument masses. Arise for

- trumpets 3.10-5… 0.001 Nms^{-1}

and for

- tubas 2.10-5… 0.0002 Nms^{-1},

thus 0.1 % … 10 % of the achievement fitted into the sound production. Also this should notice the musician. Both achievements can be reduced by decrease of the possible oscillation ways, thus more rigidly built instruments. A tone dependence could not be determined. More rigid instruments take up less achievement to the wall oscillation. For the sound production is to more energy at the disposal. Since no tendentious frequency response of the effects could be proven, the question arises, on which again and again the sound differences described by musicians are based. A possible explanation is that the wind player as a function of the necessary achievement changes his embouchure and thus the sound.

6. INSTRUMENTS PACKED IN SAND

In order to study wall effects under extreme conditions, the instruments were packed in each case in 15 kg quartz sand and blown in the comparison to the normal condition as well as measured concerning the feed impedance process.

Figure 6: Sand back-filling of a trumpet

The vibratory level of the wall is lowered by the packed in sand around more than 10 dB. The measured tendency of instruments packed in sand sinks around 10… 15 cent in particular in middle tonal range (Figure 7). Determined differences in the level and in the spectrum in spectator position and at the player ear could be attributed in the long run to the additional directive effect of the equipment.
The test musicians described uniformly a more difficult control of the instruments packed in sand. This phenomenon could be

clarified, by blowing an instrument of the same type so that the musician could not touch also this instrument with the hands (Figure 8). Similarly problems arose. The musician uses thus obviously the sense of touch for control of the instrument. After equal some exercise the musicians could blow both instruments on and determined no more differences.

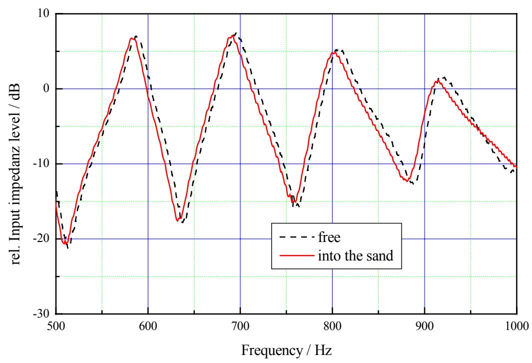

Figure 7: Feed impedance process cut out trumpet

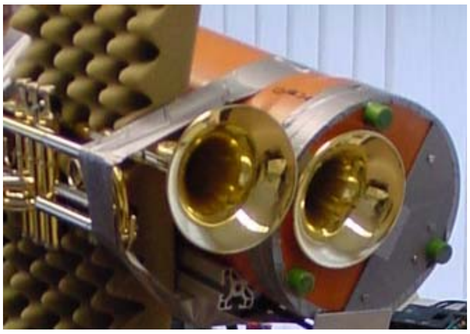

Figure 8: Two type-same trumpets

7. MATERIAL CHANGES

In the context from work to the Vuvuzela, we made measurements of simple brass instruments of very different materials:

- brass, l = 410 mm, m= 118 g (without mouthpiece)
- paper, l = 410 mm, m= 23 g (without mouthpiece)
- polystyrene, l = 500 mm, m= 44 g.

Figure 9: Simple instruments, (aluminum mouthpiece, m = 34 g)

Sound (1 m before bell) and the wall vibrations (a point on the bell) during the tone attack and during the statio-nary state were observed. One is surprised when blo-wing, as small the perceptible differences fail. The following diagrams show spectra and time signals of wall vibrations and radiated sound. The paper model shows clearly stronger wall oscillations in the tone attack. This leads to a slower increasing of the sound. The delay is approximatly 15 ms until 20 ms.

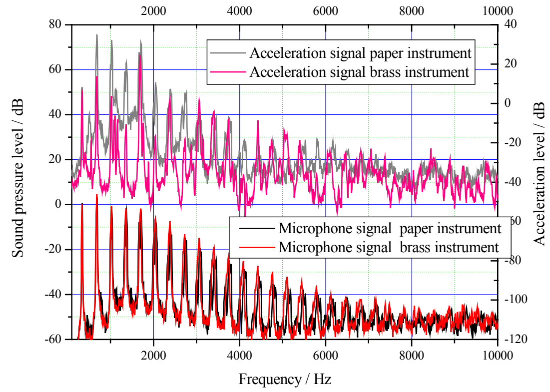

Figure 10: Acceleration and sound spectra of the tone attack of paper and brass instrument

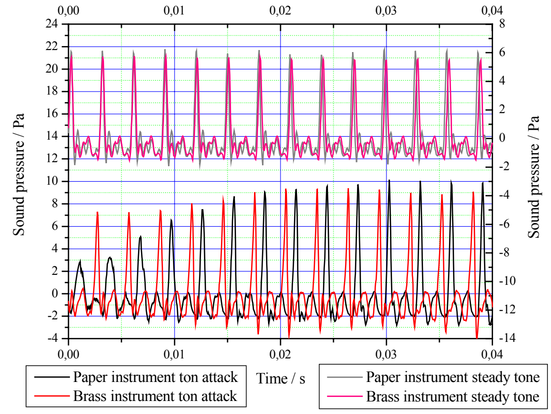

Figure 11: Acoustic signal of tone attack and stationary tone of paper and brass instrument.

8. CONCLUSIONS

We find two influences of the wall oscillations on the sound of the instrument: An indirect influence over the wind players and a direct influence due to migration of energy into the wall oscillation. The wall oscillations noticed with the hands use a set of wind players as control display for the current oscillation state of the air column. In particular this technology seems of importance in situations, in which the player hears himself badly. The player reacts to different wall oscillations of individual instruments with a changed embouchure. This leads to change in the sound color. Those take listeners really notice the changes.

The direct influences are clearly smaller, by which energy is removed from the acoustic vibrations of the air column. The effect is clearest in the range of the tone attack. Although they are technically quite provable, they become however only with the employment of extreme material variants, those use in practice not really find really perceptible.

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