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PRESENTS

MUSICIAN´s PERCEIVED TIMBRE AND STRENGHT IN (TOO) SMALL ROOMS

by Tor Halmrast

ABSTRACT

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MUSICIAN´s PERCEIVED TIMBRE AND STRENGHT IN (TOO) SMALL ROOMS

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ABSTRACT

Musicians often rehearse in small rooms. This might give problems regarding sound pressure level and timbre (German: klangfarbe). The rehearsal rooms for the Norwegian Armed Forces´ Band North in Harstad were investigated introducing different absorbers (curtain, corner/bass-absorber and wall absorber).

The investigations included calculations/measurements of room acoustic parameters and recordings/analysis of a short Test Composition for trombone, tuba, Bb-clarinet and Bb-trumpet in the different room settings. Recordings with "in-ear" microphones were used for analysis of timbre and "perceived reverberation". The results indicate that there are two issues that might be more important than plain reverberation time criteria: *1) Room resonances in the bass (tuba and trombone etc.), 2) "Shimmering" for high pitched instruments (clarinet)* A sound source with a given, constant sound power will be reduced some 3-5 dB when a small rehearsal room is modified from "moderate absorption" (curtain) to "well absorbed" (curtain, corner absorber and some wall absorbers. Musicians will compensate unconsciously, so effective reduction will in practice be some 1-2 dB less.

1. TEST COMPOSTION

A one minute test composition was prepared for the investigation, see App. A. Fig. 1 shows the trombone version. The version for trumpet is simply an octave transposition, but the versions for tuba and clarinet were further modified with extra octave transpositions of sections in order to fill the tonal range (ambitus) of each instruments (clarinet extra ***8va*** for some phrases and some tuba phrases additional ***8va*** basso). The total "score" of the Test Composition is shown in Appendix A, also for additional instruments for further investigations. The instrumental recordings were done with a Sennheiser "In-Ear"-Microphone and simultaneously with a calibrated omni microphone typically 1.5 m and 45^0 from the bell of the instrument. All recordings were done in "wav", 16 bits, 44.1 kHz. Each instrument was recorded solo, in strict tempo MM ♩ = 120 using a silent, flashing metronome.

Fig. 1 Test Composition. Trombone

2. THE REHEARSAL ROOM

The rehearsal room has dimensions: L=4.33m, W=2.14m, and H=2.28m. A calculation of room resonances is given in Appendix B.

Fig. 2 Room with absorbing curtain only (Non-dampened room)

The only absorbing material is a flexible curtain which was present in all the musical tests. In order to eliminate any "false reverberation", there was no piano in the room. The extra absorbers introduced were a corner/"bass" absorber in form of a roll of Rockwool, and 4 Rockfon Cosmos wall absorbers (thickness 100mm) (see fig. 3)

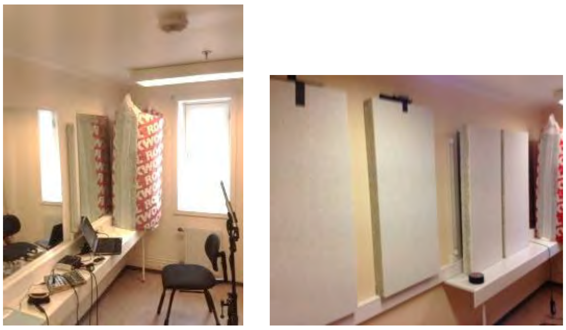


Fig. 3 Corner/"bass"-absorber and Cosmos wall absorber (Dampened room)

All walls and the ceiling are in gypsum boards, and the floor is a light, floating floor on mineral wool. A rough Odeon (Sketch) model of the room is shown in fig. 4.

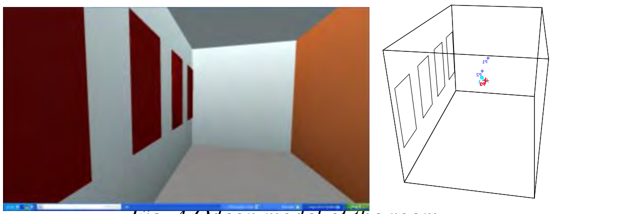


Fig. 4 Odeon model of the room (Dark = absorber)

3. REVERBERATION TIMES

3.1 Calculated/Simulated Reverberation Times

An overall Odeon Reverberation Time calculation gives that the room with plain gypsum walls (no curtain) will have a too long reverberation time (see fig.5). In daily use the only absorber in the room was a curtain on one of the sidewalls, one chair and a bench. This situation is referred to as *"non-dampened"*. The calculated reverberation time for this situation also gives rather high values. (see Fig.5)

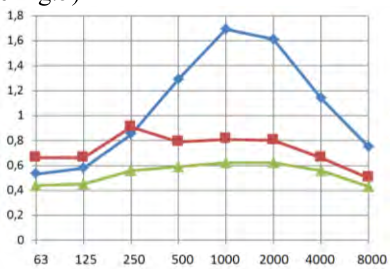


Fig. 5. Results from Odeon simulation of rehearsal room.
Upper: Gypsum on all walls
Middle: Curtain on one sidewall
Lower: Curtain and wall absorbers on the other side wall

These preliminary room simulations might give the impression that the reverberation time is sufficiently low in the bass due to the bass absorption of the gypsum walls. We shall see that we do have problems with room resonances, and need to introduce a bass-/corner-absorber.

3.2 Measured Reverberation Times

The reverberation times and Schroeder curves with/ without the flexible curtain are shown in fig. 6.

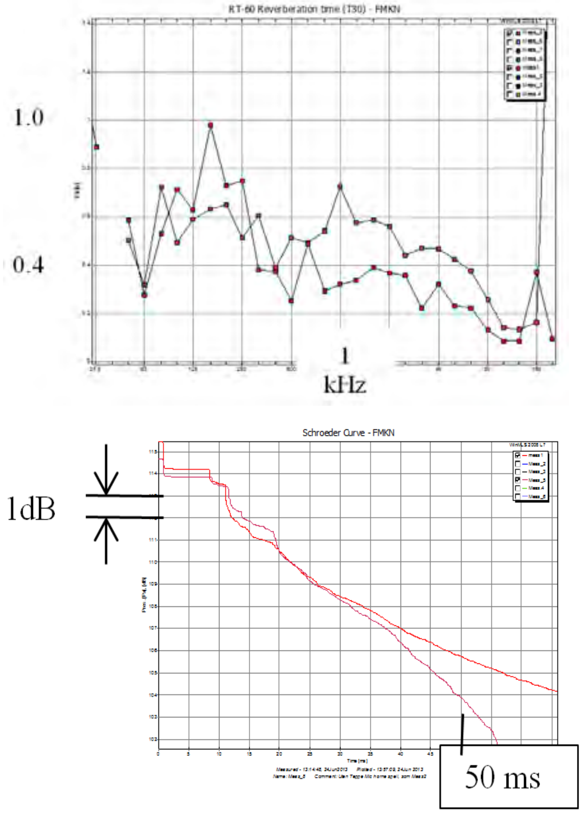


Fig. 6. Reverberation Time and Schroeder curves with/without flexible curtain

For the situation with flexible curtain and corner/"bass-absorber, we get the following reverberation time (fig. 7)

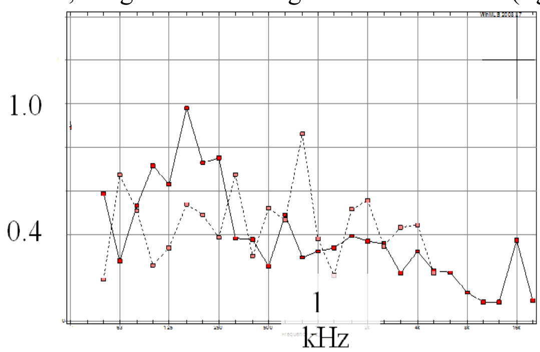


Fig. 7. Reverberation time with/without corner absorber (in addition to flexible curtain)

We see that the corner absorber gives nice reduction for the bass (80-250 Hz). The moderate rise in reverberation time for mid-frequencies (1 kHz - 4 kHz) when introducing the corner absorber is somewhat strange, but might, to a certain degree, be explained by the fact this "low-budget" corner absorber is covered with plastic, which gives some reflections closer to the measuring microphone. The most important is the nice reduction for the bass.

When introducing the Cosmos wall absorbers in addition, we get the reverberation time shown in fig. 8. (for two receiver positions).

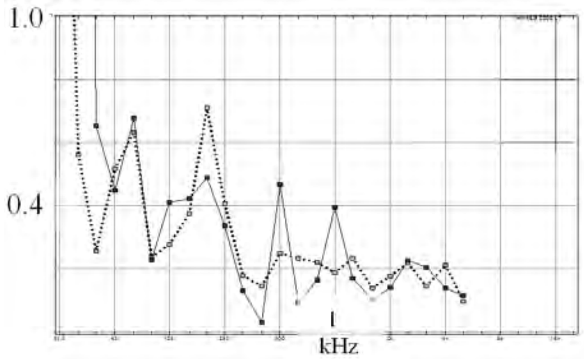


Fig.8. Reverberation time with all absorbers (2 measurement points for the same situation)

We see the known fact that measuring reverberation times in small rooms is highly sensitive to microphone position, due to the resonances, especially for the lower frequencies (see Appendix B). Usually one takes the average of several measurement positions to get a statistical value, but that will "hide" the observed problem of room resonances in small rooms for music and their influence on the perceived timbre, which is a main issue for this paper.

A simplified overview of the measured reverberation time for the different settings of absorbers is given in fig. 9.

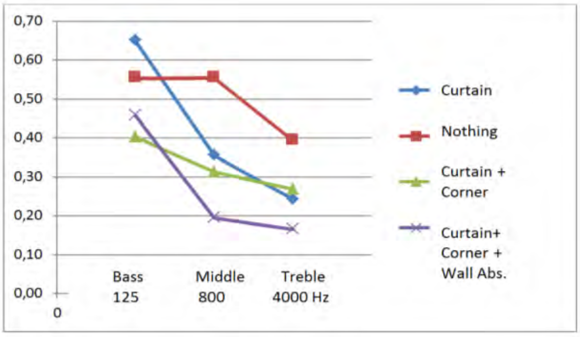


Fig. 9. Overview of Reverberation Times (Tm: Nothing: 0.5, Curtain: 0.42, Curtain+Corner: 0.33, All: 0.27)

We see that the curtain reduces the reverberation time for middle frequencies from some 0.55 s to some 0.35 s, and the four wall absorbers reduces the reverberation further down to some 0.2 s for these middle frequencies. For the bass frequencies the corner absorber is the most important. The results are somewhat unclear due to the resonances and because we included just a few measuring positions, but the reduction due to the corner absorber is some 0.2 s in the bass. The absorption coefficient for such a corner absorber is not given in text books or product information, but by a very rough estimation from the reductions of reverberation times in fig. 7, the corresponding absorption area of such a simple corner absorber, just a roll of Rockwool, is some 4m^{2}Sabine for the frequency region 80-250 Hz (see Appendix E)

3.3 Musician´s Perceived Reverberation

As stated in [2] it is possible to use your hand-claps and tongue drops (clicks) recorded with microphones in your own ear to judge your perceived reverberation in a room for middle frequencies. When evaluating the reverberation times from such recordings, we must eliminate the strong direct sound by taking the calculations from some -20 to -35 dB (instead of from -5 to -35 dB as for standardised measurements with longer distances between source and receiver, as in ISO 3382-1 and -2).

Figure 10 shows the Schroeder curves and reverberation times the for tongue drops in the "dampened" situation (red) and in the "non-dampened" situation (blue).

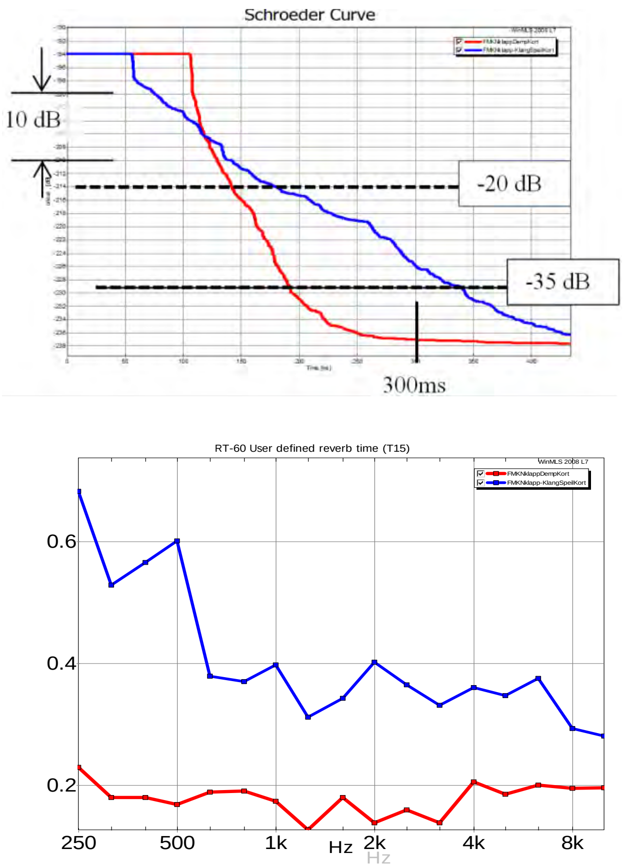


Fig. 10. Schroeder curves and Reverberation times for In-Ear measurements of own tongue drops. (User defined T15, taken from -20 dB to -35 dB). Blue: Non-Dampened room. Red: Dampened room

We see that the dampened room is perceived ("in-ear") as having an even shorter reverberation time than what was measured by standardised methods in 3.2.

4. SOUND PRESSURE LEVELS

4.1 Measurements with loudspeaker

The measured reduction of sound pressure level when introducing the different absorbers is shown in fig. 11.

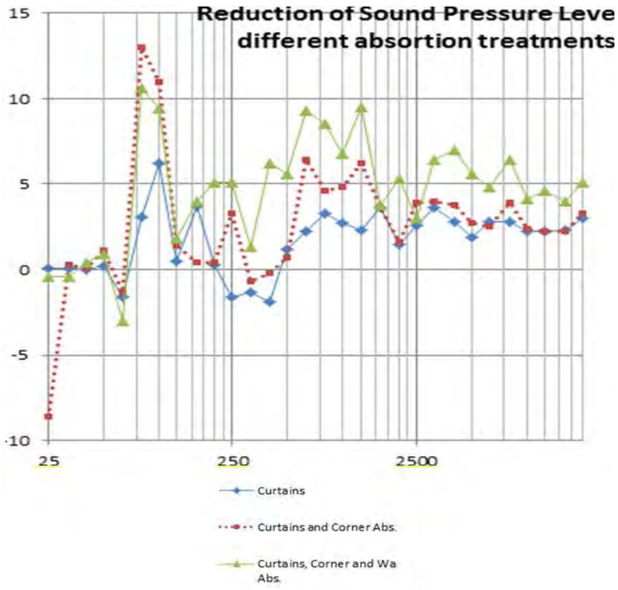


Fig. 11. Reduction of Sound pressure level by introducing different absorption treatments (1/3 octave)
Curtains only (mean=1.7 dB)
Curtains and Corner Absorbers (mean=2.6 dB)
Curtains, Corner and Wall Absorbers (mean=4.7 dB)

The measurements more or less follow the theoretical 3 dB reduction in level when dividing the reverberation time by two. Such a calculation is of course only correct for diffuse sound fields. Our small rehearsal room is far from diffuse due to dominating room resonances and small size, but the result is interesting.

For the middle frequencies (315 - 2000 Hz) we have the following mean values for the reduction of sound pressure levels: *Curtain: 1.5 dB, Curtain + Corner: 3 dB and Curtain+Corner+Wall: 6.5 dB),* so that the change between having just curtains ("non-dampened") and all absorbers ("dampened") is 5 dB.

4.2 Measurements of musicians playing the Test Composition

Unfortunately it is not possible to calibrate the Sennheiser "in-ear"-microphones with a pistophone. Therefore, calibrated sound pressure levels were measured simultaneously with a calibrated omni directional microphone positioned app. 1.5 m from the instruments, 45° to the side of the main direction of the "bell". First we will look at these "in the room" recordings in the "non- dampened" rehearsal room (just curtains), compared to the "dampened" situation with all absorbers (corner and wall absorbers in addition). Later we will look more into details of the "in-ear"-recordings, (uncalibrated, but recorded at equal input level, so that comparisons between them are possible).

4.3 Calibrated, "in the room" measurements of sound pressure levels from musicians

A histogram of dBA_{fast} versus time for the whole Test Composition (trombone) is shown in fig. 12, with/without curtains.

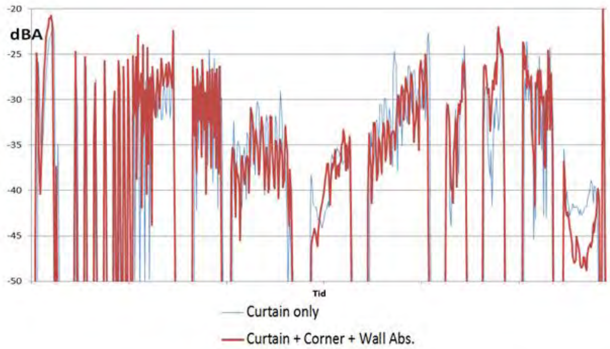
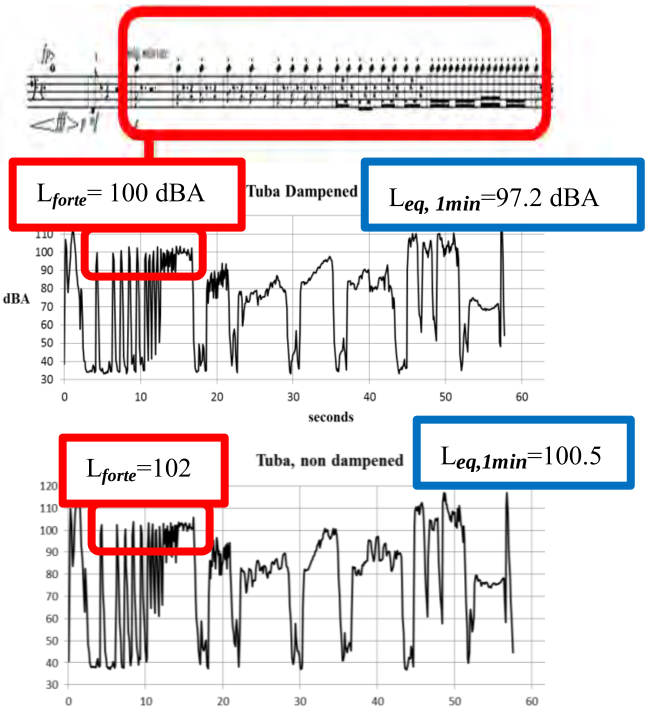


Fig. 12. Histogram of dBA/time.
With/without curtains

The middle part of the piece might indicate a 2-3 dB reduction with the curtain, but we find that in this representation, the difference between the levels of the recordings with different room damping for the trombone is not very clear.

We will now look at the dBA_{fast} levels for the 10 s forte, ***f***, section of the test composition (marked in red on top of each curve in fig. 13) for both the "dampened" (all absorbers) and "non-dampened" (just curtain) situations, for each instrument. Shown is also the energy based equivalent levels, Leq for the whole test composition (marked with blue circles).



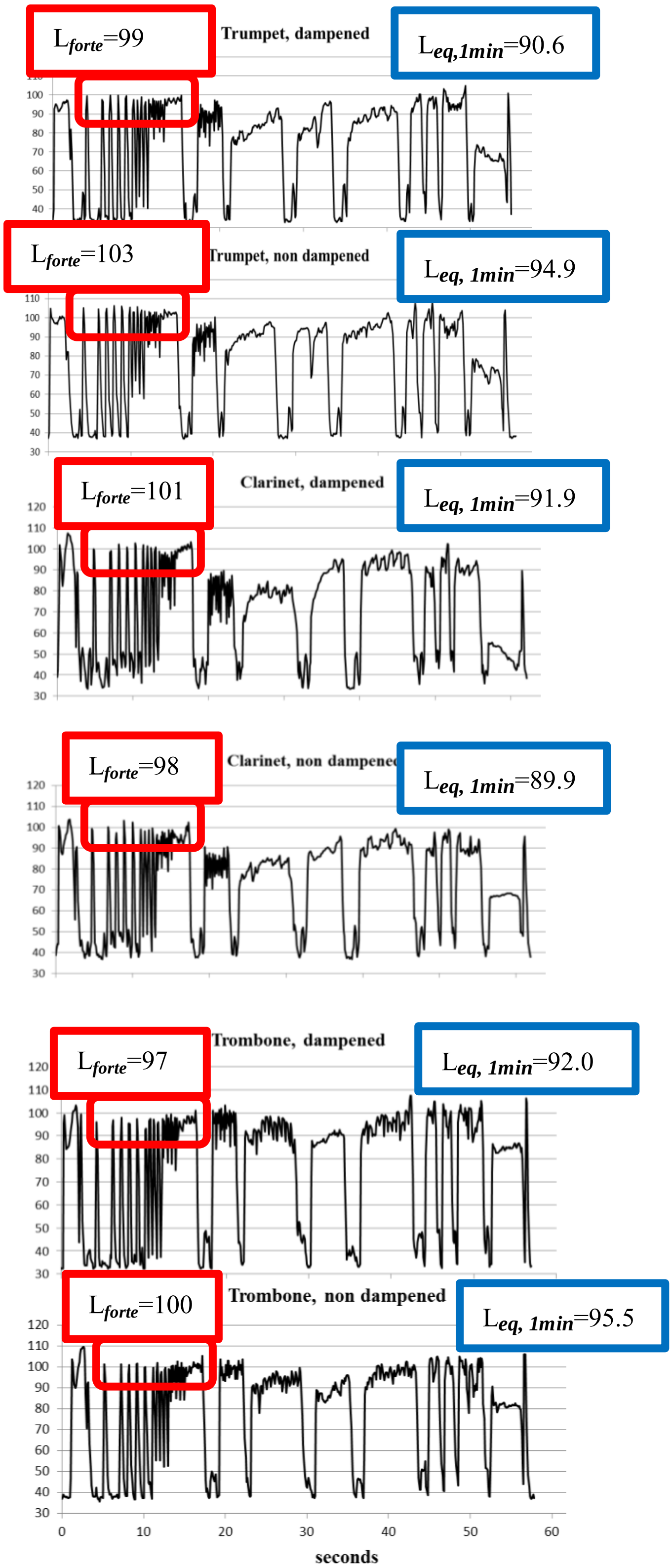


*Fig. 13. Histogram dBA_{fast} versus time for instruments. Test Composition in Dampened/Non-Dampened room. Red squares indicate forte, **f**, section*

Apart from the clarinet, we see the following reductions in Lp for the 10 s forte, ***f***, section (red circles):

Tuba:	*102 - 100 = 2 dBA*
Trumpet:	*103 - 99 = 4 dBA*
Trombone:	*101 - 97 =3 dBA*

For Leq (dBA) measured "in the room" for the duration of the whole test composition (blue) we find:

Tuba:	*100.5 - 97.2 = 3.3 dBA*
Trumpet:	*94.9 - 90.6 = 4.3 dBA*
Trombone:	*95.5- 92.0 =3.5 dBA*

For clarinet seems to "over"-adjust to the damped acoustics, and play stronger. The Leq is actually higher in the dampened room than in the more reverberant! This might be "personal", and is discussed later.

Conclusion, Sound Pressure Level: The measured reduction in sound pressure level at the musician´s ear when introducing the extra absorbers is 1-2 dB less than the reduction measured with a constant loudspeaker source. This means that the musicians (not only the clarinet) compensate for the reduced "answer" from the room by playing 1-2 dB stronger.

4.4 Comparisons with theoretical studies

Mayer [1] gives information on typical Sound Power Levels, Lw. The following table shows an adaption.

Instrument	***(ppp)***	***pp-p***	***p-mf***	***f***	***ff-(fff)***
Tuba	76	93	<<<	**106**	112
Trumpet	77	89	<<<	**101**	111
Clarinet	55	75	<<<	**94**	107
Trombone	73	93	<<<	**101**	113

For our further calculations, we will use the sound power levels for ***f*** in this table and compare with the measured results from 4.3.From general acoustic theory we have the following equation between sound power (Lw) for a sound source and sound pressure level (Lp) in a room with Volume V and Reverberation time T: [1]

$$L_p = L_w + 10log\left(\frac{Q}{4\pi r^2} + \frac{4T}{0.16V}\right) \qquad (1)$$

where Q is the directivity factor for the source. For a rough estimate one might be tempted to assume a diffuse soundfield and discard the direct sound by dropping the first part of the parenthesis. This would of course not be quite correct in such a small room, so in the following table we have calculated the sound pressure levels both: a) without this first part of the parenthesis, (first numbers

[1] Sound pressure level can be taken using the parameter Strength, G [dB], but we did not have calibrated measurement equipment available.

in black in the table) and b) with the first part of the parenthesis (last numbers in black in the table below). A Q-factor of 1 is chosen (as for a point source)[2]. Our room Volume is 2.4 x 4.33 x 2.28 = 23.7 m^3, so for the different reverberation times, we get the following calculated sound pressure levels (Lp) for *forte*, ***f***, compared the measured ones from 4.2 (in red and parentheses):

	T=0.5 s	T=0.35 s	T=0.2 s
Tuba	103.2-103.6 **(102)**	101.7-102.3	99.2-100.2 **(100)**
Trumpet	98.2-98.6 **(103)**	96.7-97.3	94.2-95.2 **(99)**
Clarinet	91.2-91.6 **(98)**	89.7-90.3	87.2-88.2 **(101)**
Trombone	98.2-98.6 **(100)**	96.7-97.3	94.2 -95.2 **(97)**

The measured values are in very god agreement with theory for tuba and trombone, but some 4 dB higher for the trumpet. The clarinet is 8-10 dB stronger than calculated; see the comments on clarinet in 4.3 and 4.5. The "strange" behaviour of the clarinet is probably in order to avoid the "shimmering" timbre, se chapter 5.

4.5 "In-Ear-Measurements" of Test Composition

Detailed analysis was performed also on the "in-ear"-recordings (which were done simultaneously with the "in room" recordings discussed in 4.3). As mentioned, these measurements are not calibrated dB SPL, but all these measurements were performed with the same settings, so comparisons between them are possible. We will first look into the recordings of the clarinet, because this instrument showed somewhat strange result in the previous chapter. The "in ear"-histograms for the "dampened room" and the "non-dampened room" are shown in fig. 14.

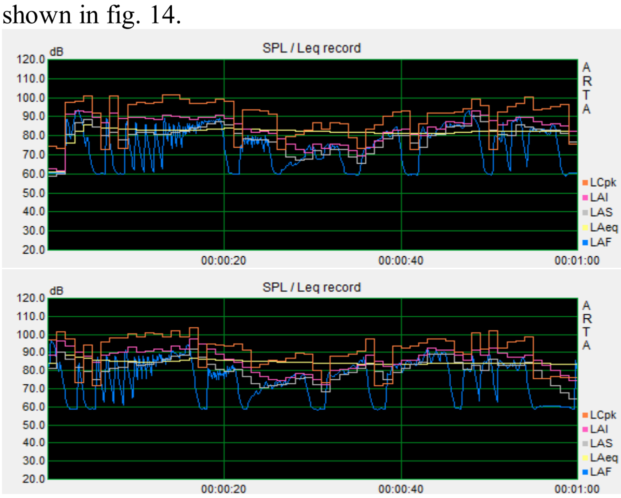


Fig. 14 Histogram In-Ear-Recordings of the Test Composition. Upper: Dampened Room, Lower: Non-Dampened room Clarinet (non-calibrated)

The following table gives the main results: (not calibrated)

CLARINET	LAeqT	LCpeak max	Sone	Phon
Whole Piece				
Dampened	81.9	101.7		
Un-Dampened	83.3	103.9		
10 s Intro				
Dampened			42.3	94.0
Un-Dampened			50.4	96.5

We see that these "in-ear"-measurements" give some 1.5 – 2 dB reductions for the clarinet when the room is changed from "non-dampened" (just curtains) to "dampened" (curtains, corner absorber, wall absorbers), so these "in-ear-recordings" indicate that the additional damping with corner and wall absorbers give a perceived "in-ear" reduction also for the clarinet. The Phone value is also reduced some 2.5 when dampening the room.

For the Trumpet, we get the Histograms shown in fig. 15

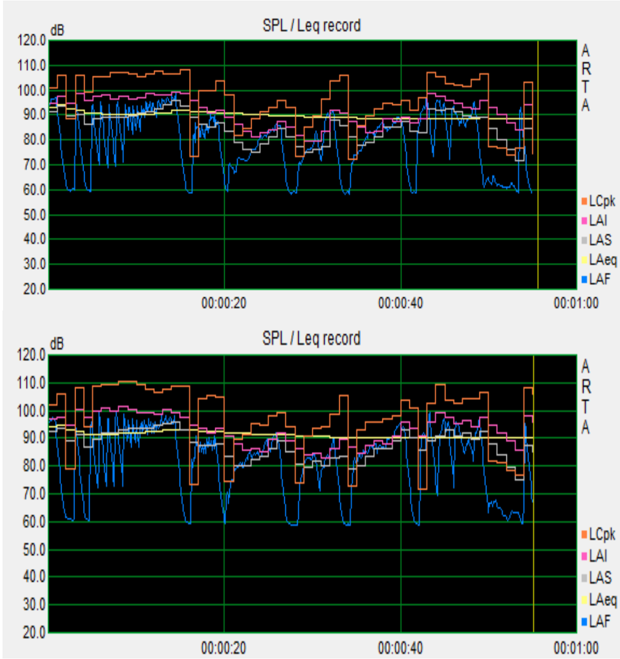


Fig. 15 Histogram In-Ear-Recordings of the Test Composition. Upper: Dampened Room. Lower: Non-Dampened room Trumpet

The main results for trumpet: (not calibrated)

TRUMPET	LAeqT	LCpeak max	Sone	Phon
Whole Piece				
Dampened	88.4	108.5		
Un-Dampened	89.9	105.2		
10 s *forte*, *f* Intro				
Dampened			71.8	101.7
Un-Dampened			90.2	105.0

We see that Leq for the trumpet is reduced some 1.5 dB when dampening the room[3]. The reduction in Phone for the whole piece was some 3.2 dB, which is about 1 dB

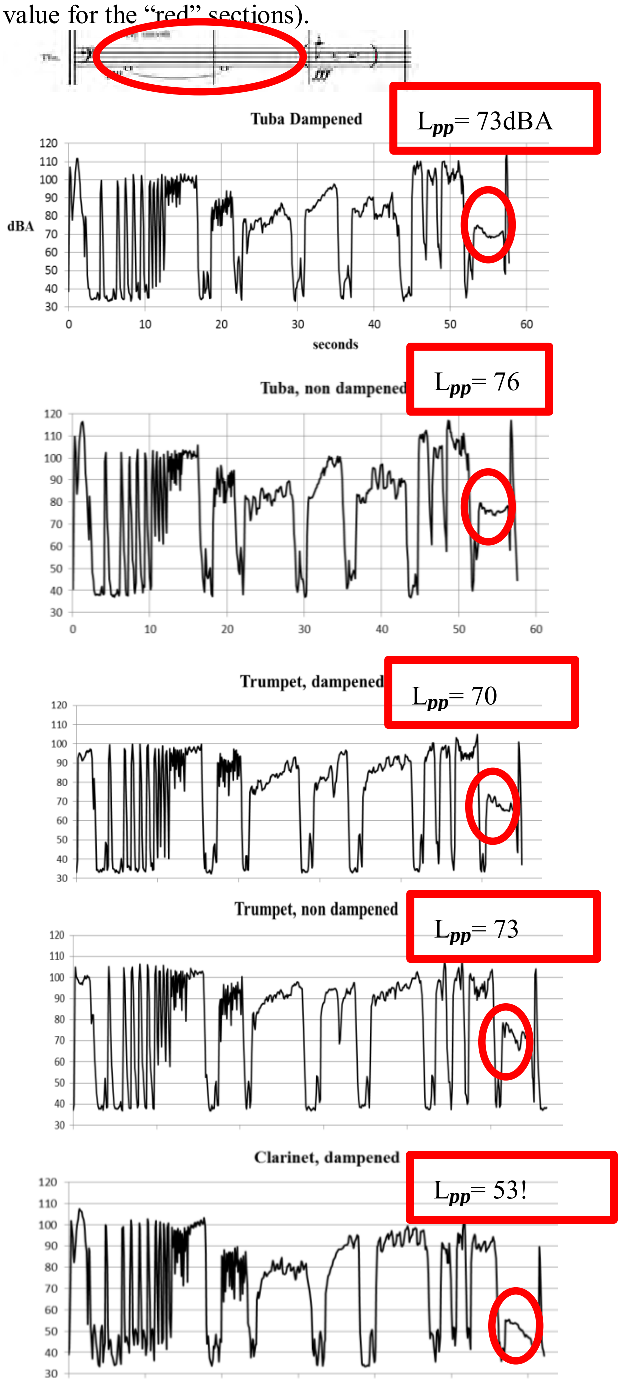
[2] The measuring position r=1.5 m and 45^0 from the direction of the bell might give a Q somewhat lower than 1.

[3] We should notice that the Sone levels, which might be a better parameter for perceived loudness, show a greater reduction.

less than the reduction for the "in room" measurements in 4.3. However, for this recording of the trumpet, the max level during the period was actually higher when the room was dampened (see table above). This is due to one single ***ff***-note played strong, and is not statistically relevant, but shows that dampening a room is not, by itself, necessarily a security for lower sound pressure levels for short, strong notes.

4.6 Sound pressure levels when playing pia-pianissimo

All discussion so far has been for ***f*** (or ***ff*** and ***fff***). Analysis for a part of the Test Composition that calls for "*very smoothly* ***pp***" is shown the in figure 16. (The fact that the played tones are not very "steady" in strength will not be discussed further. We will look at the mean value for the "red" sections).



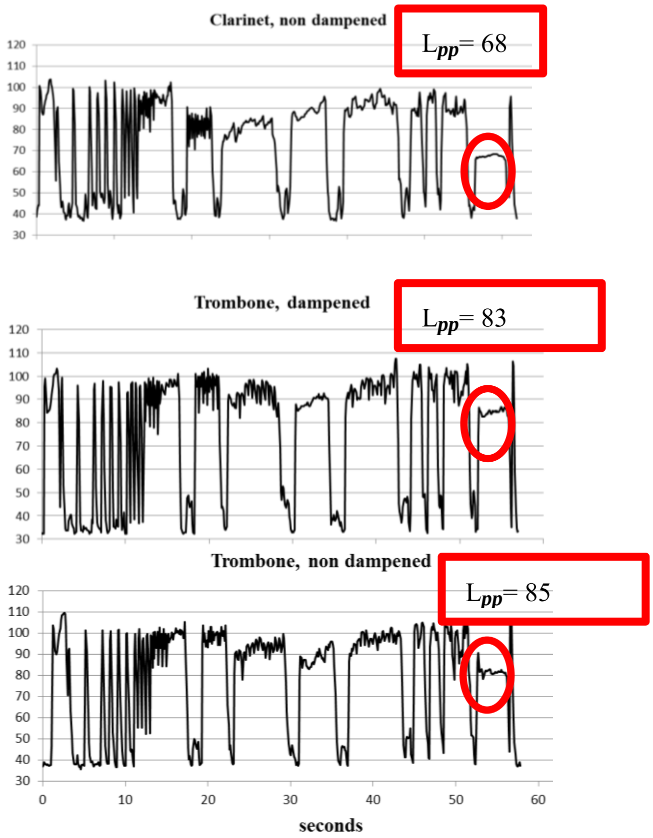


Fig. 16. Histogram dBA versus time for instruments.

From fig. 16 we see that for the brass instruments the sound pressure levels for the ***pp*** section are reduced by 2-4 dB when dampening the room. This is almost the same as for the 10 s section of the composition played ***f*** (1 dB lower than in 4.3). So, the conclusion for brass playing ***pp*** is about the same as for playing ***f***. This means that: **Musicians (brass) use the same dynamic range both for dampened and non-dampened room,** (when asked to follow the indications in the score).

For the clarinet we see a 10-11 dB reduction from "non-dampened" to "dampened", which again might be "personal" or an example of the fact that a clarinet is more easily played soft than brass instruments and thus might use a larger dynamic range.

We also need to consider that the rather high background noise in the room (see App. D) might influence when playing ***pp***).

4.7 Loudness when musicians face different surfaces

It is commonly believed that one should not rehearse playing directly into a reflecting wall. For the non-dampened situation, the trombone was recorded playing a) Towards the curtain, b) Towards the reflecting wall (with gypsum and mirrors) and c) Towards the door (the length of the room). The differences of sound pressure levels as mean values for the whole test composition were surprisingly low (within +/- 0.7 dB), and thus not significant. Actually the measurement towards the curtain was the strongest, followed by the one facing the door. For changes in timbre for the different directions, see 5.2.

4.8 Perceived "In-Ear" changes in Strength (G)

Our measuring equipment did not include a calibrated sound source for measuring Strength, G, but we did measure the differences of uncalibrated G with tongue drops/clicks recorded in the musician´s own ear as signal.

Figure 17 gives the results from analysing G from "in-ear recording" of own tongue clicks in the different settings for the rehearsal room.

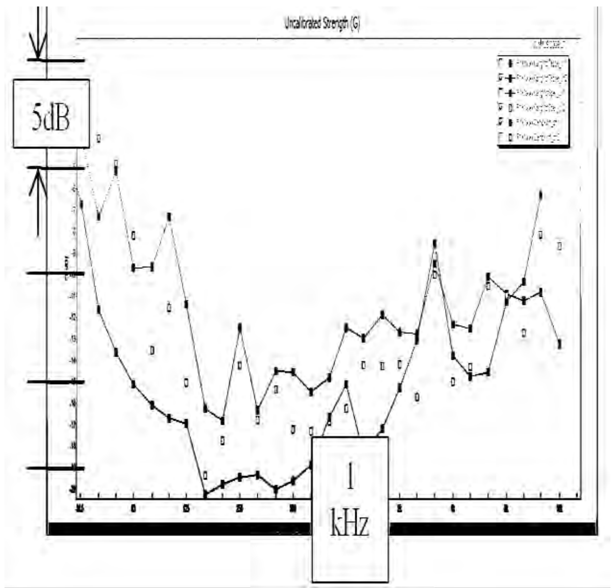


Fig. 17. Musician's perceived reduction of uncalibrated G (strength) of In-Ear recording of own tongue clicks. Upper: Non Damped room (just curtain) Lower: Damped room (curtain, corner, wall)

We see some 3-5 dB reduction of Perceived Strength (G) when introducing all absorbers. (The measurement method using tongue drops does not give sufficient signal to noise ratio for the higher frequencies, so the measurements for this frequency range (and the low bass) will not be discussed further).

5. SPECTRUM "KLANGFARBE"/TIMBRE

5.1 "In-Ear"-measurements of Timbre

The "in-ear"-recordings were analysed in spectrograms/ sonograms. (see fig. 18). Notice that length of short notes is somewhat longer in the non-damped settings (lower part of fig. 18).

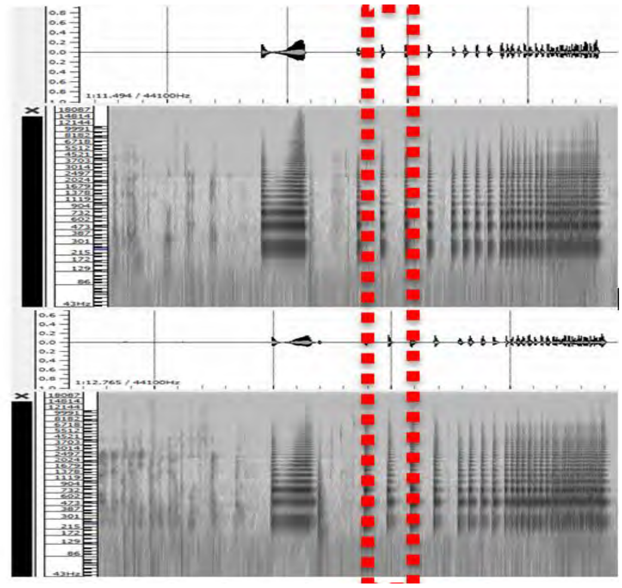


Fig. 18. Clarinet. First part of Composition. Upper: Dampened Room. Lower: Non Damped room. Increased length of notes when longer reverberation. (logarithmic frequency scale)

Changes in timbre were clearly heard between different settings of absorbers. However, these perceived changes are not clearly seen using common settings for overall sonograms for the tuba. (see fig. 19).

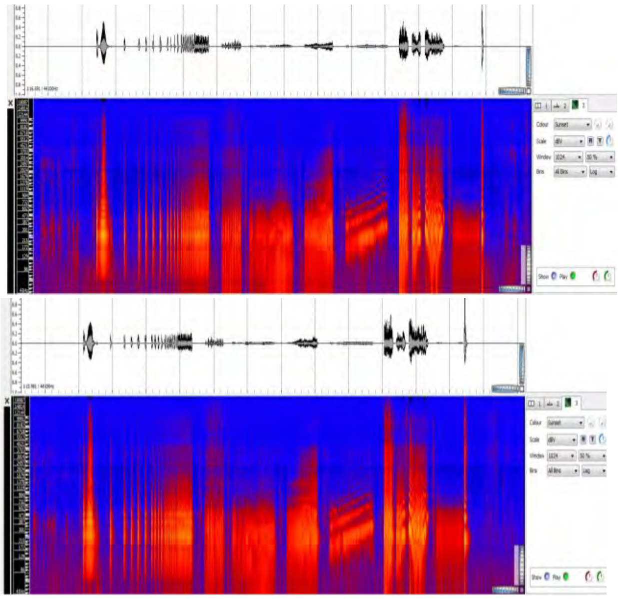


Fig. 19. Sonogram of Tuba "in ear"-recording. Upper: Damped room. Lower: Non-Damped Room. (log frequency scale)

A more precise frequency analysis of the trumpet, however, shows some 5 dB increase for frequencies around 2000 Hz, and also some 13 dB increase for the peak slightly over 500 Hz. (see fig. 20 and 21 for trumpet).

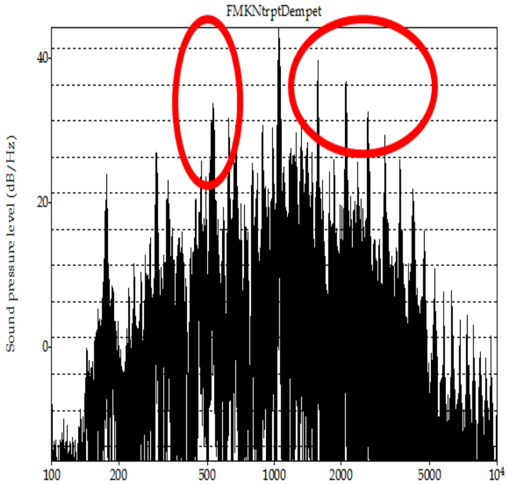


Fig. 20. Frequency analysis of the whole piece. Trumpet. Dampened room. Logarithmic scale

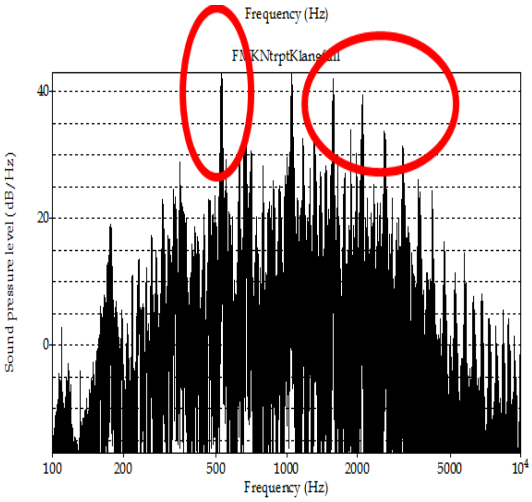


Fig. 21. Frequency analysis of the whole piece. Trumpet. Non-dampened room. Logarithmic scale

Also for the clarinet, the perceived changes in timbre when playing in the non-dampened room, was clearly heard, especially for the higher register, but not easily detected using common settings for sonograms. (see fig. 22).

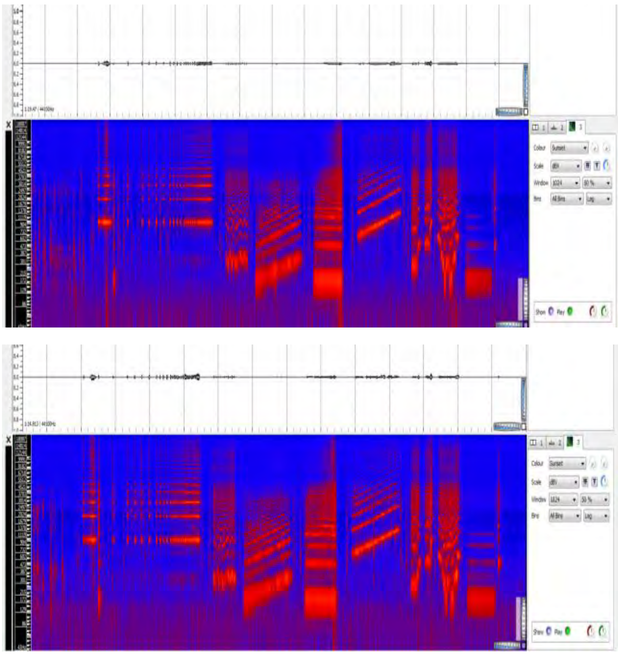


Fig. 22. Sonogram of Clarinet "in ear"-recording. Upper: Damped room. Lower: Non-Damped Room. (log frequency scale)

Even a frequency analysis of the whole Test Composition does not show very clear difference between "non-dampened" and "dampened" (se fig. 23), but there seems to be a reduction at 3000 Hz.

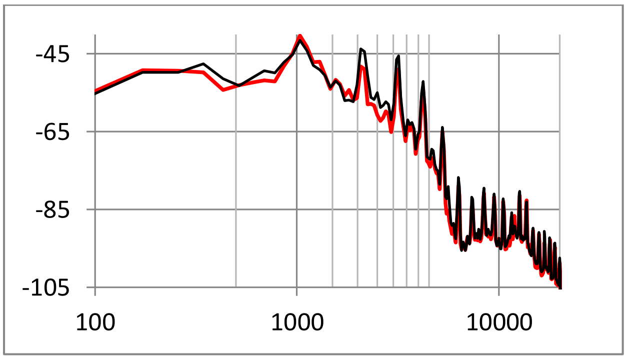


Fig. 23. Frequency analysis of whole Composition. Clarinet. Red=Dampened room. Black=Non Dampened

The clearly perceived changes in timbre for the clarinet were mainly heard in the high register at forte, ***f***. Therefore we will again examine the first 10 s forte-section of the piece (after the first note) more closely (the same section as investigated in fig. 13, but now for clarinet two octaves higher, sounding high C "natura", around 1 kHz).

If we take frequency analysis of these 10 seconds of the piece, we see clear changes in timbre between damped and non-damped room, especially for the second, third and fourth partials which are increased by some 5 dB. (see fig. 24). Even the fifth partial is clearly increased. This gives the unpleasant sharpness for this high register in the "non-dampened" room.

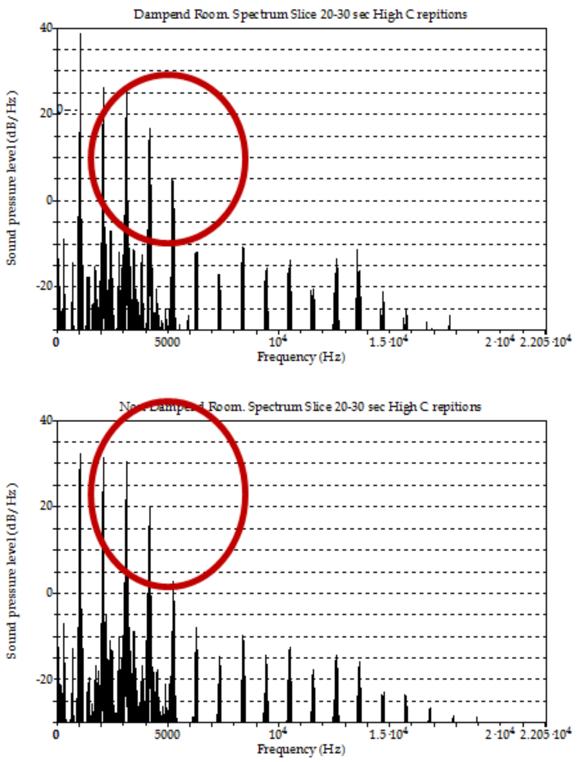


Fig. 24 Freq. analysis of 10 s of clarinet playing high C natura (app. 1kHz). Upper: Dampened Room. Lower: Non-Dampened Linear freq. scale

This is even clearer when using a logarithmic frequency scale (see Fig. 25)

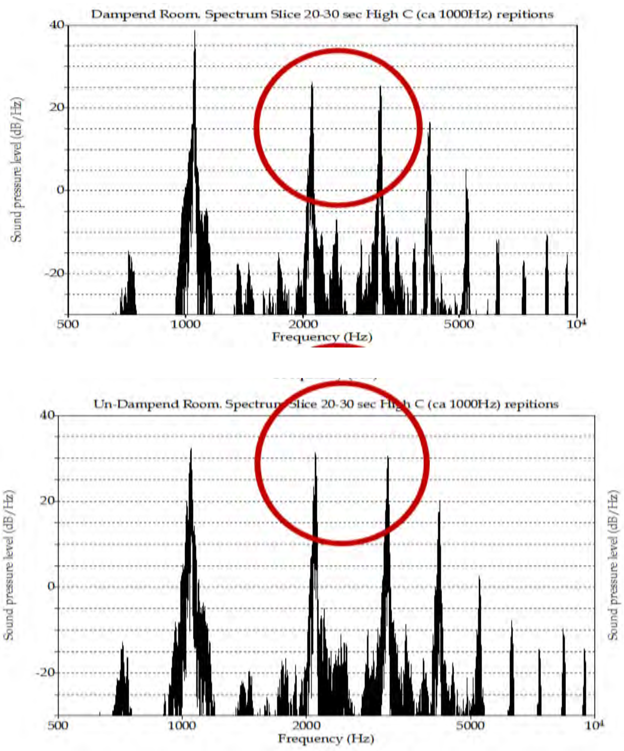


Fig. 25. Freq. analysis of 10 s of clarinet playing high C natura (app. 1kHz). Upper: Dampened Room. Lower: Non-Dampened Logarithmic frequency scale.

This increase in higher frequencies can be seen also when analysing the Spectral Centroid (see fig. 26).

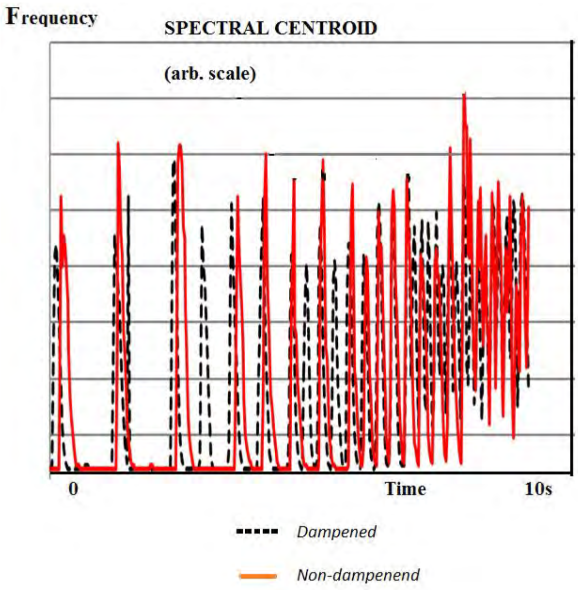


Fig. 26. Spectral Centroid versus time of the 10 sec of high pitched clarinet, 10 s of short notes just after the beginning of the test piece.

Analysis in Pure Data (Pd) (see Appendix C) gives that the peak spectral centroid for the whole, short 10 s section is raised from 3617 Hz to 3930 Hz for the "non-dampened" room compared to the "dampened" room for the clarinet. Similar analysis for the trumpet gave a rise in Spectral Centroid from 3132 Hz for the dampened room, to 4281 for the non-dampened room.

"By ear" this high frequency "shimmering" was more annoying for the clarinet than for the trumpet. This is of course mainly because the clarinet plays this section one octave higher than the trumpet[4], but perhaps also because the clarinet produces only odd numbered harmonics, so that the partials are more spaced.

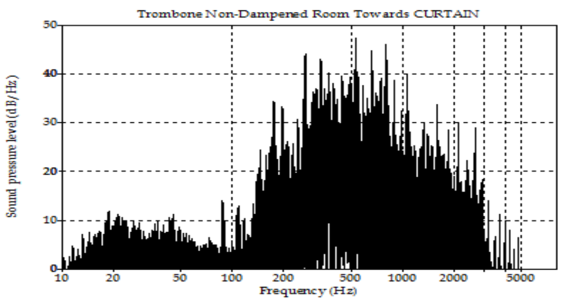
The unpleasant sharpness for 2-4 kHz is in the frequency region where the human ear is most sensitive and the kind of sounds we should be most aware of regarding the possibility of hearing loss.

[4] The situation might be the opposite for a big band lead trumpet playing *8va*.

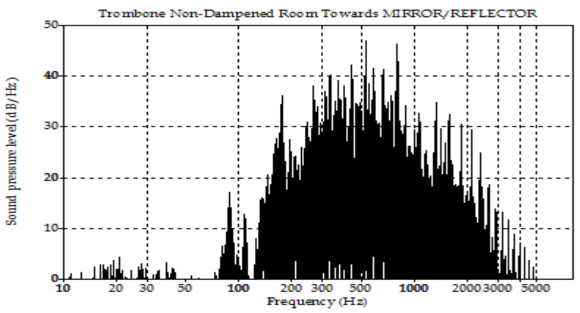
5.2 Timbre when musician face different surfaces

For the non-dampened room the trombone was recorded playing the Test Composition in different directions: a) Facing towards the curtain sidewall, b) Facing the reflecting sidewall (mirror and gypsum) and c) Facing the short wall with door towards the corridor.

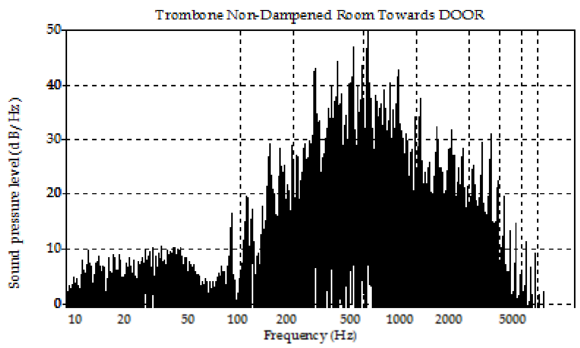
In 4.7 it is shown that we, surprisingly, did not get significant differences in sound pressure level for the different directions. Also for the frequency analysis in fig. 27, the differences are not large. Towards the curtain gives somewhat less for the 150-200 Hz region. Facing the door gives some dB more in the mid-frequencies. This is surprising because this is the direction with the longest distance to a surface in the direction of the bell. The reason why this direction is the "strongest" might be that it is the direction that gives the trombone player the most freedom, and it his favourite direction when rehearsing in such small room.



a)



b)



c)

Fig. 27 Frequency analysis of the composition. "In-Ear-mic". Trombone in different directions.
a) Facing curtain.
b) Facing reflecting wall.
c) Facing door (reflecting).
Logarithmic scale.

The changes in timbre between different directions are more clearly observed when we analyse the parameter Sone. Here is an analysis of the 10s forte, ***f***, section, showing Sone/Bark. Both measurements are for the "non-dampened" room. The blue curve is for the trombone facing the curtain, and the yellow is for facing the mirror.

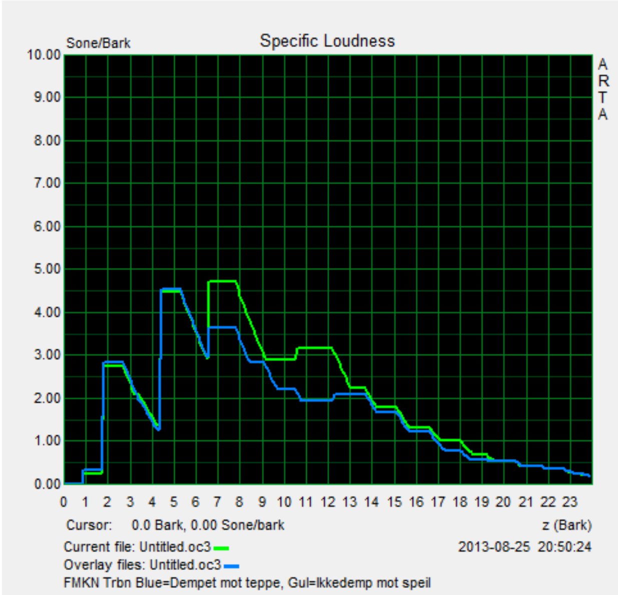


Fig. 27b Sone/Bark
Trombone.
"Non-dampened" room
Blue = Facing the curtain
Yellow= Facing the mirror

We see an increase Sone in the Bark-region 7-12 (which might correspond to centre frequencies of 700-1600 Hz). This increase of perceived loudness is easier seen in this analysis than the traditional frequency analysis in fig. 27.

6. ROOM RESONANCES

Appendix C shows 1) Perceived room resonance in the room when singing, 2) Calculations of room resonances, 3) Theoretical positions of max sound pressure levels in the room due to each resonance and 4) Practical comments on room resonances. Introducing the corner absorbent was clearly perceived as beneficial for reducing the room resonances, not only for the measured reverberation times shown earlier, but also for the overall well-being in the room, talking with a normal tenor voice (example ca. 110 Hz, see App. B). The waterfall curves without corner absorption is shown in Fig 28. (curtain only, "non-dampened")

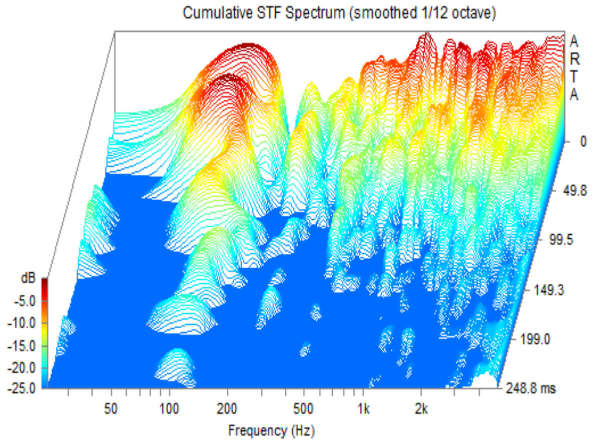


Fig. 28. Waterfall Curve without corner absorption (curtain only, without corner/bass-absorber)

The corresponding Energy Decay and Schroeder-curve, filtered 1/1 octave, 125 Hz is shown in fig. 29.

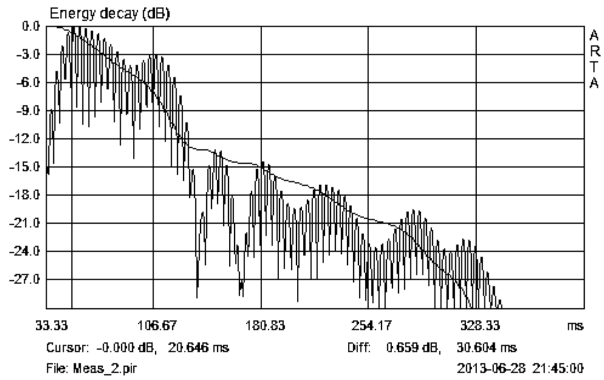


Fig. 29. Energy Decay and Schroeder curve. 1/1 oct. 125Hz (curtain only, without corner/bass-absorber)

The dominant "wave"-like shape of the waterfall curve (the decay around ca. 100 Hz in fig. 28) seems to "crawl" somewhat side to side, which might indicate that there are several room resonances "fighting" around the same frequency band. (see discussion in Appendix C).

The waterfall curve with corner absorber, and wall absorber (in addition to curtain), is shown in Fig. 30.

"

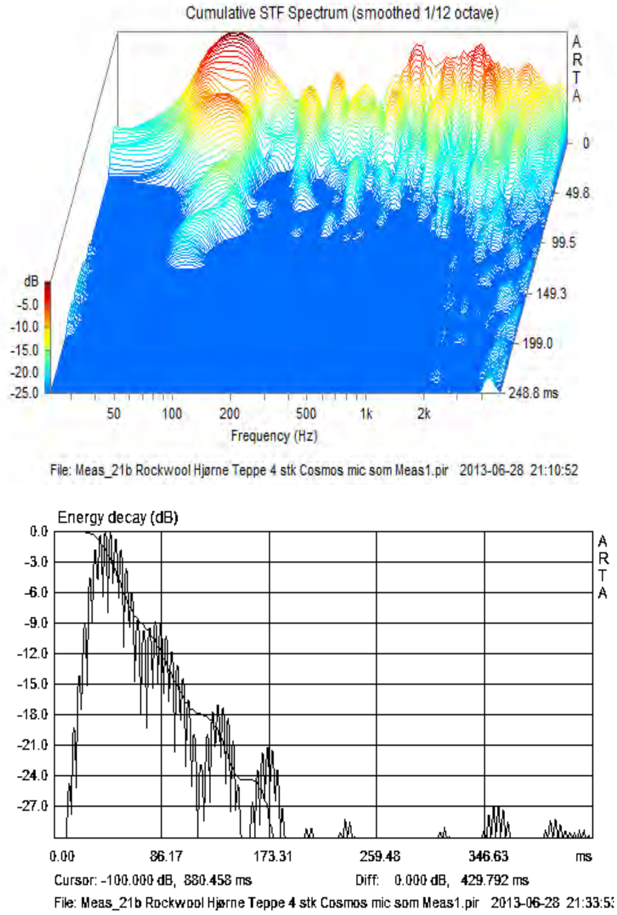


Fig. 30. Waterfall and corresponding Energy Decay and Schroeder curve with corner absorber (and curtain)

We see that the corner absorber reduces the resonances. Without the corner absorption it was easy to locate perceived resonance peaks in the room "by ear" when talking/singing. This effect was reduced with the corner absorber. The tuba player was pleased with having more control in the low register. There are, however, still some resonances, mainly between ceiling and floor and between the short walls (between door and window), se App. B.

The test composition includes two sections of chromatic scales. Unfortunately, common FFT sonogram settings give inadequate resolution for such low frequencies, so there is no clear signs of specially resonating notes in the two chromatic scale passages of the Test Composition for the trombone (fig. 31 compared to fig. 32), nor any clear indication of the perceived fact that the room resonances were much less pronounced in fig. 31 with corner (and wall) absorbers.

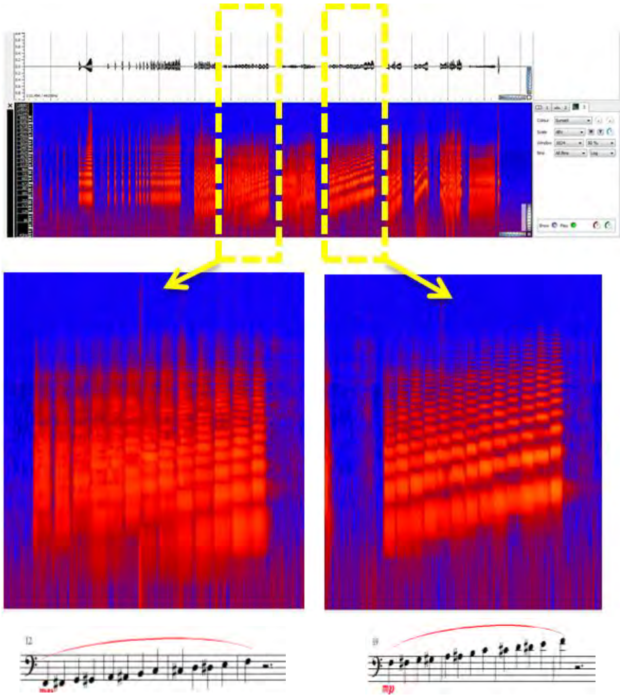


Fig. 31. Sonogram with zoom in for the two chromatic passages. Trombone. Damped room. Logarithmic frequency scale

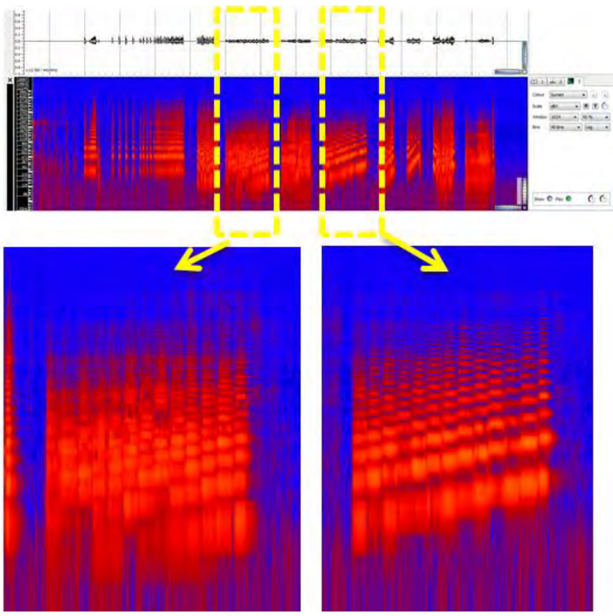


Fig. 32. Sonogram with zoom in for the two chromatic passages. Trombone. Non-Damped room. Logarithmic frequency scale

Even with sharper settings for the sonogram, there are no clear signs of the influence of room resonances on strength of particular tones of the chromatic passages. (see fig. 33 and 34).

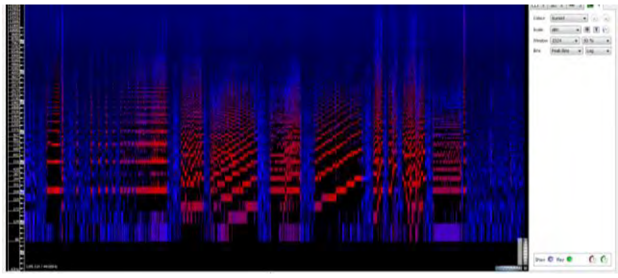


Fig. 33. Sonogram of Trombone. Sharper settings. Dampened room

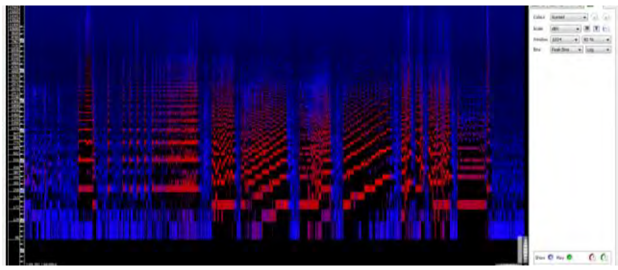


Fig. 34. Sonogram of Trombone. Sharper settings. Non-Dampened room

Also for tuba, the frequency resolution in this common spectrogram setting is not sufficient for checking the influence of room resonances (se fig. 35).

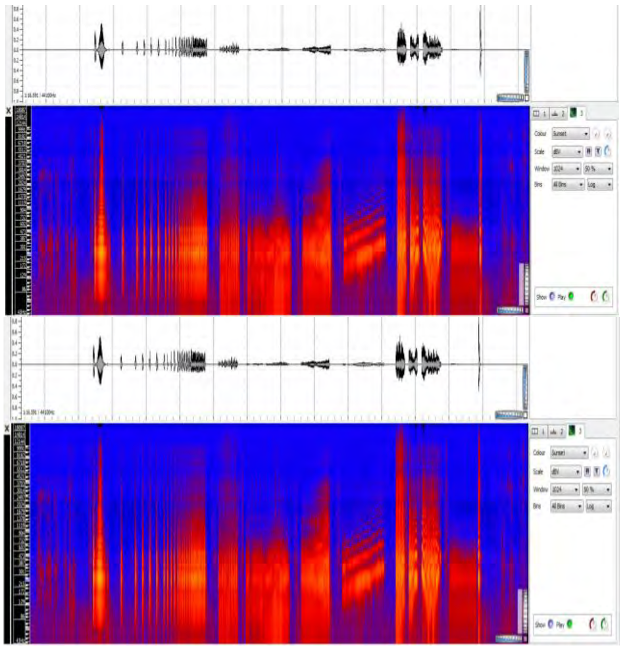


Fig. 35. Sonogram of Tuba. Sharper settings.
Upper: Non-Dampened room
Lower: Dampened

7. CHECK FOR COMB FILTER COLORATIONS

Coloration is clearly perceived “by ear” when singing/talking, especially in the “non-dampened” room. As given in [3], close, discrete reflections may give comb filter coloration. This is shown for several investigations on orchestra platform in concert halls, and for echolocation for the blind [4]. Fig. 36 shows frequency analysis of “In-Ear” recordings of handclaps (linear frequency scale) in our rehearsal room. We see only small signs of comb filter coloration, even for the “non-dampened” situations. The reason might be that we have several comb filters overlapping with about the same “Comb-Between-Teeth-Bandwidths”.

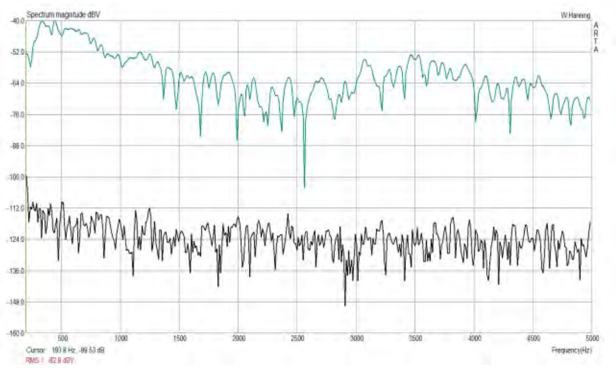


Fig. 36 Frequency analysis of In-Ear recordings of handclaps. Upper: Non-Dampened room. Lower: Dampened room. Linear frequency scale

Additional analysis showed no clear Autocorrelation for these recordings, which mean that several reflections (ceiling, floor etc.) arrive at about the same time, and that the sound field is not sufficiently correlated as to give clear comb filter effects.

8. MUSICIAN´s PREFERENCES and PRACTICAL SOLUTIONS

For our short tests, all the musicians preferred the “dampened” settings, with all absorbers (curtain, bass-/corner-absorber and wall absorbers), but this setting might perhaps be too “dead” for long-time rehearsal. For a practical solution, the corner-/bass-absorber should be permanent (probably in the form of a slit panel in front of a corner cavity filled mineral wool), and the wall absorbers should be somewhat flexible.

The measurements and simulations were performed and analysed in: WinMLS, ARTA, Audio Tools (Studio Six) w/calibrated iMic, Sonic Visualiser, Praat, Odeon, Wavelet Sound Explorer and Pure Data (Pd)

CONCLUSIONS

Practical measurements and recordings of different instruments in a small rehearsal room have been performed. It is shown that a sound source of a given, constant sound power will be reduced some 3-5 dB when the room is modified from “non-dampened” (only curtain) to “dampened” (curtain, corner absorber and some wall absorbers). Musicians, however, will compensate unconsciously, so the effective, perceived reduction will in practice be some 1-2 dB lower.

The changes in timbre between a moderately dampened room and a well dampened room are not easily detected by using common settings in sonograms etc. However, for high pitched instruments, a rise in Spectral Centroid is observed due to higher relative strength of harmonics in the 2-4 kHz region which include the frequencies most dangerous for damage of hearing.

The main effect of a well absorbed room in practice is to 1) Reduce the “shimmering” of high frequencies, and 2) Dampen (some of) the room (bass) resonances, which for small rooms are in the region of the fundamentals for tenor/bass instruments.

Of course such dampening of room resonances should theoretically also give a more consistent level when playing different tones that corresponds or not to the resonances, but in practice for rehearsal, the musicians did not complain much about possible lack of egality in the frequency response, so this effect of dampening the room resonances seems not to be as important for musicians as they are for loudspeaker playback in sound control rooms of similar (small) size.

The aspects of 1) reducing “shimmering” in the high frequencies and 2) room resonances in the bass is more important than a common reverberation time approach when designing (too) small rooms for music.

Acknowledgments

Thanks to the patient musicians and producers of the Norwegian Armed Forces´ Band North, Harstad.

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[2] Halmrast, T: “When Source is also Receiver” ISRA, Int. Symp. on Room Acoustics, Toronto 2013.

[3] Halmrast, T: ”*Orchestral Timbre: Comb-Filter Coloration from Reflections”.* Journal of Sound and Vibration (2000) 232(1), 53-69

[4] Halmrast, T: *“More Combs”* Proceedings of the Institute of Acoustics (UK) Vol. 33. Pt.2, and EAA/Forum Acusticum, Aalborg, 2011

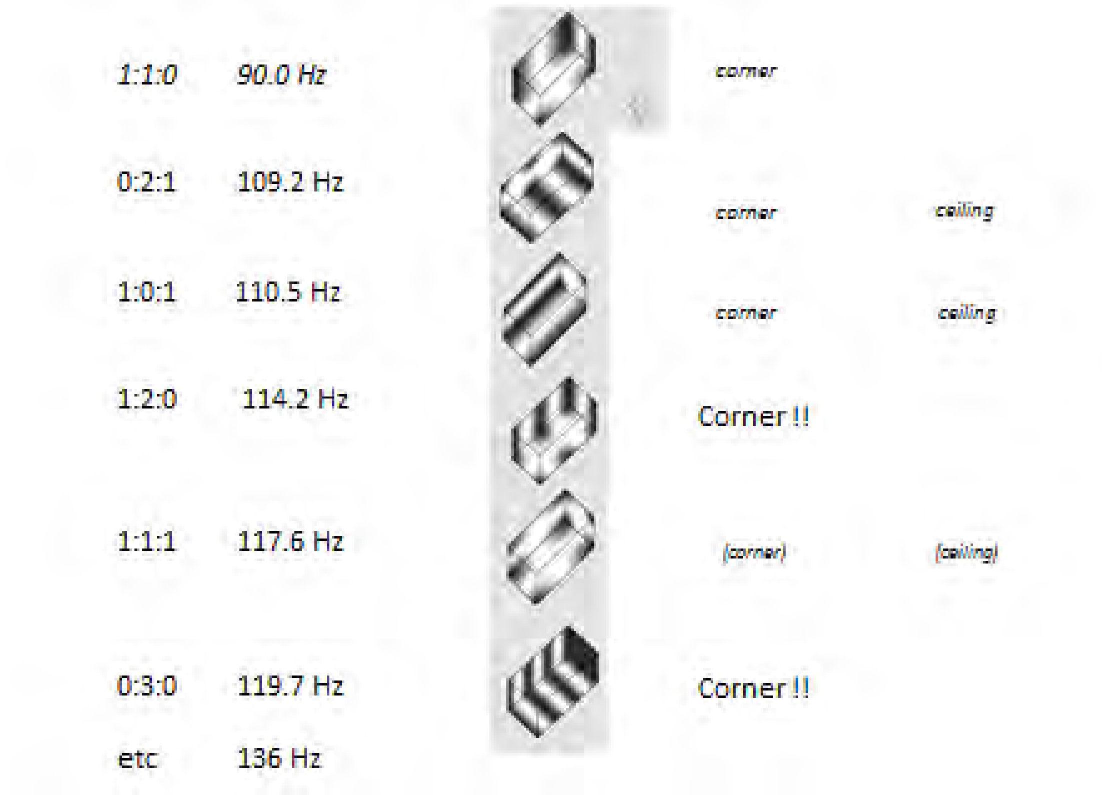
APPENDIX A


Rehearsal Room Test
Tor Halmrast
Stright in rythm!
Flute
Clarinet in B♭
Alto Sax.
Trumpet in B♭
Trombone
Tuba
molto, molto stacc.
marcato
opt. 8vb
+ sing!, dirty, growl
very smooth
GP

APPENDIX B
Room Resonances

B1) PERCEIVED RESONANCE
Even in Dampened room, a (tenor) male voice gives a resonance of app. 111 Hz in the room, by singing/humming.

B2+3) CALCULATIONS AND VISUALISATION OF ROOM RESONANCES
(Black=High Sound Pressure levels)



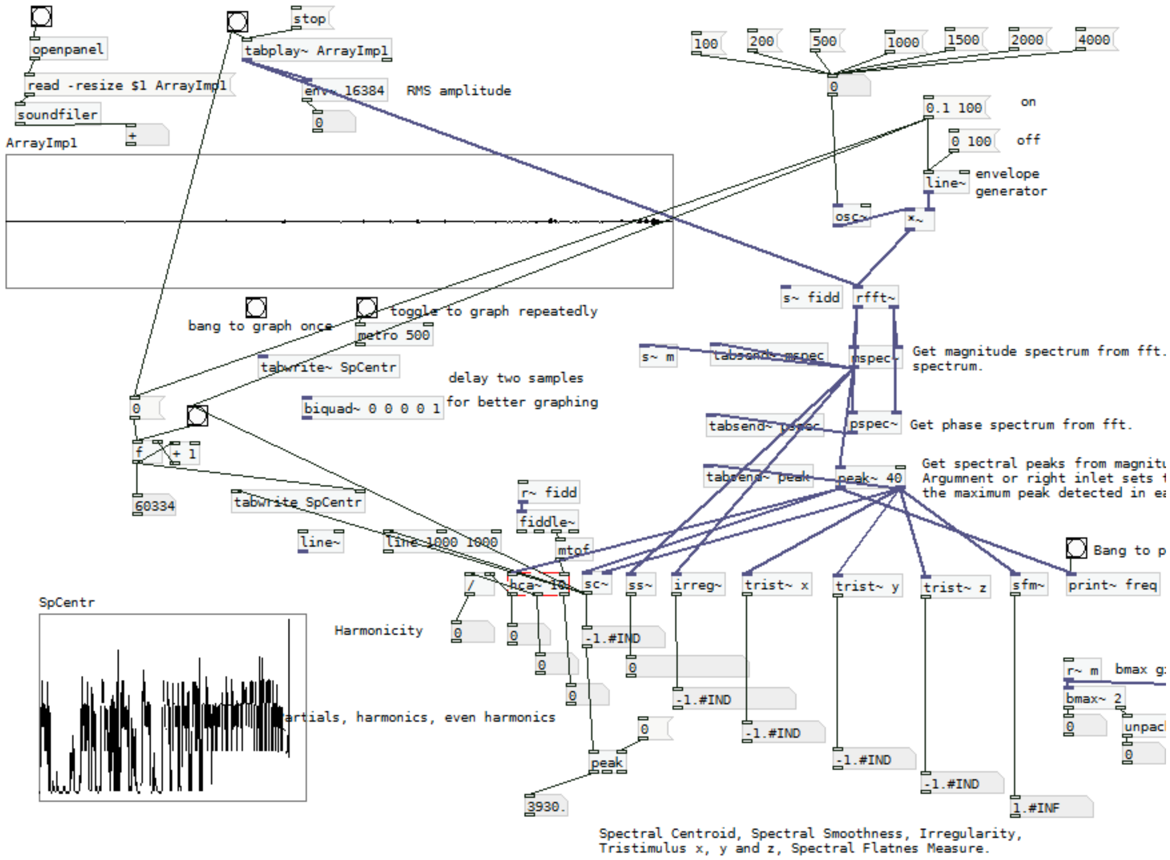
B4) COMMENTS ON RESONANCES
The W and H dimensions are quite close, giving almost the same frequency for two (three) resonances: 0:2:1 (109.2 Hz), 1:0:1 (110.6 Hz) and 1:2:0(144.2). The “swinging”/”crawling” shape of the resonant frequenc(ies) in the decay shown in the waterfall curves in Ch. 6 is probably because these resonances interfere.

Resonance 0:2:0 (109.2 Hz) and 1:0:1 (110.6 Hz) have almost the same as our “singing” resonance of 111Hz. Resonance 1:2:0(114.2 Hz) is the one that will be most reduced by the position of our corner absorber. The reduction of reverberation time and resonant decay in the dampened version in Ch.6 is probably due damping of resonance 1:2:0 due to corner absorber. (Our corner absorber is likely also to dampen resonance 1:0:0, (which is not so easily triggered by a (tenor) voice).

Resonances 0:2:1, 1:0:1 and specially 1:1:1 (117.6 Hz) would probably be more effectively reduced if the corner absorber could be placed all the way down to the floor. (This was not possible in our test because of the bench at the sidewall, see fig. 3)

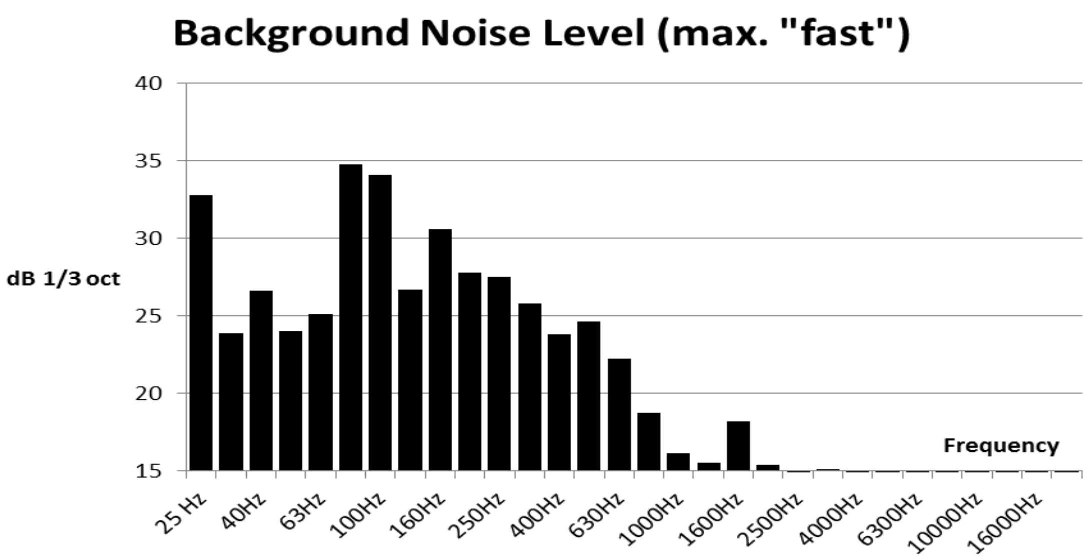
APPENDIX C

Pure Data (PD) patch for measuring Peak of Spectral Centroid



APPENDIX D

Maximum Background Noise during the measurements



APPENDIX E

Absorption area of Corner Absorber (Roll of Rockwool)

		L	*W*	*H*	*V*	
		4,33	*2,14*	*2,28*	*21,13*	
from fig. 7	**T30**			**m2Sab**		
Hz	**No Corner Abs**	**Corner Abs.**	**Diff. T30**	**No Corner Abs**	**Corner Abs**	**m2 Sab Corner Abs**
80	0,7	0,3	0,4	4,8	11,3	6,4
125	0,65	0,33	0,32	5,2	10,2	5,0
163	0,9	0,55	0,35	3,8	6,1	2,4
200	0,73	0,52	0,21	4,6	6,5	1,9
250	0,75	0,39	0,36	4,5	8,7	4,2
			mean:	4,6	8,6	4,0

T=0,16V/A

A=0,16V/T