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ACOUSTICS-REPORT no. 200/2016

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Date: …03/06-2016……

Project: …...Stavanger Concert House……………
Issue: ……..Analysis of performed music
………..in different acoustic settings/reverberation times…...........................

During the presentation **"Music Shapes Rooms, Rooms Shape Music"** at the IMS conference (International Musicology Society) in Stavanger July 3rd 2016, the same piece(s) of music was performed with 3 different acoustic settings in Fartein Valen concert hall, and in one setting in Zetlitz multipurpose hall, both in Stavanger Concert House.

OVERALL CONCLUSIONS

- All listeners and musicians were surprised by how big the changes in acoustics were. Even listeners who knew the Fartein Valen hall from attending (and playing) the hall many times were highly surprised over the demonstration.

- The rough recordings do, of course, not represent the actual listening situations, but the changes between the different settings are surprisingly large also when listening to the recordings!

- Analysing the recordings, however, we find that both the sound pressure levels and the overall frequency spectra are almost the same for all settings!!

- In order to find the clearly perceived differences, we need to look closely into spectrograms, attack/release times etc., and inspect the lengths of the separate tones and how they are masked (if the reverberation is too long for the jazz/rock part), or too short, (so that each note lacks build up to a "full tone" for the strings).

- Not only the decay time, but also the attack time is longer for the most reverberant settings. For fast piano (jazz, MM=200), this prolonged decay due to long reverb "masks" the attack, and thus "smoothes" the "timbre", and reduces the "brilliance".

Surprisingly, the parameters most common for Musical Information Retrieval (MIR) etc. show NOT to be able to detect the very clearly perceived "timbral" differences between the settings. The reverberation times (and investigations of differences in tone length is the only way to show the differences. This seems to be a big "hole" in the repertoire of MIR analysis.

CONTENT

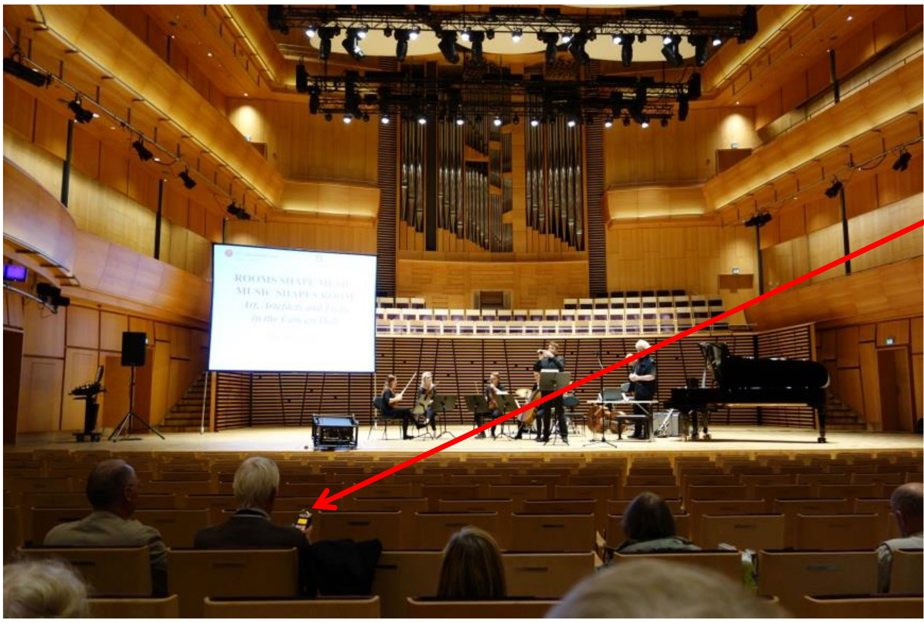
Thanks to:

Espen Berens (trpt. UiS), Svein Folkvord (double bass/el-bass, Sinus Akustikk a/s),Carl Haakon Waadeland (drums, NTNU), String quartet from the 1B1 ensemble (UiS), Jan Tro (recordings, NTNU), The technical staff at Stavanger Concert House. (Guitar and piano: Tor Halmrast).

A) THE HALLS

More information about the halls is given in Appendix

FARTEIN VALEN



Wav-recorder 8th row somewhat off center

Type:
Zoom H4n
standard
mics on tope

photo: Alex. R. Jensenius

ZETLITZ

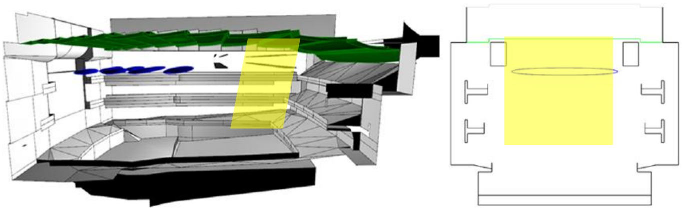
photo: Alex. R. Jensenius

B) ACOUSTIC SETTINGS

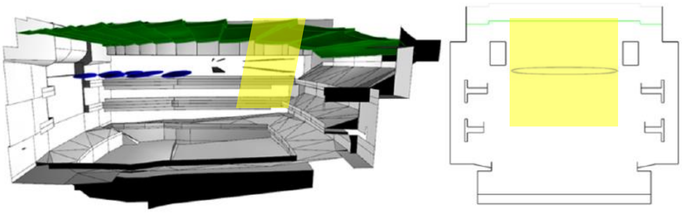
The illustrations below (adapted from the User Manual by Kahle Acoustics) shows each acoustical room setting, illustrating the height of the hall´s main ceiling and of the canopy reflectors over/in front of the stage. Also shown is the amount of absorbing curtains on the walls etc., and use of the “rehearsal curtain”. (See App. 2 for details of the hall).

“2.Chamber” (with rehearsal curtain in addition to the pictures below) The setting was something in the middle of these two Chamber Settings:

Chamber music I



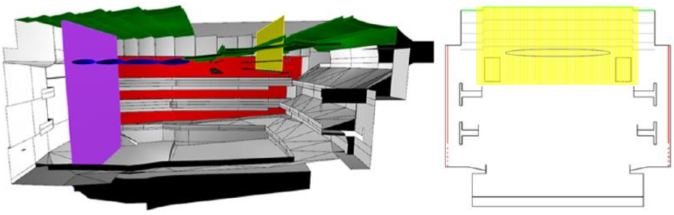
Chamber music II



“4. Amplified”

Fully dampened. Setting for Amplified Music. (Not meaning that any more instruments were amplified!!) Rehearsal curtain half/third down (to dampen reflections from the first ceiling panels up/back to the void). Curtain on side walls (floor + balconies). PS! The photo shows additional curtain/screen in front of organ, which was not used).

Heavily amplified music



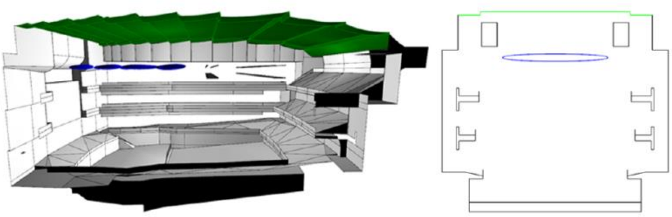
“5. Zetlitz”

Fully dampened. Small bleacher (telescopic “amphi”) in the audience area. Curtains on side balconies. Stage curtains. Musicians on the “standard/front stage”. (Back stage not in use).

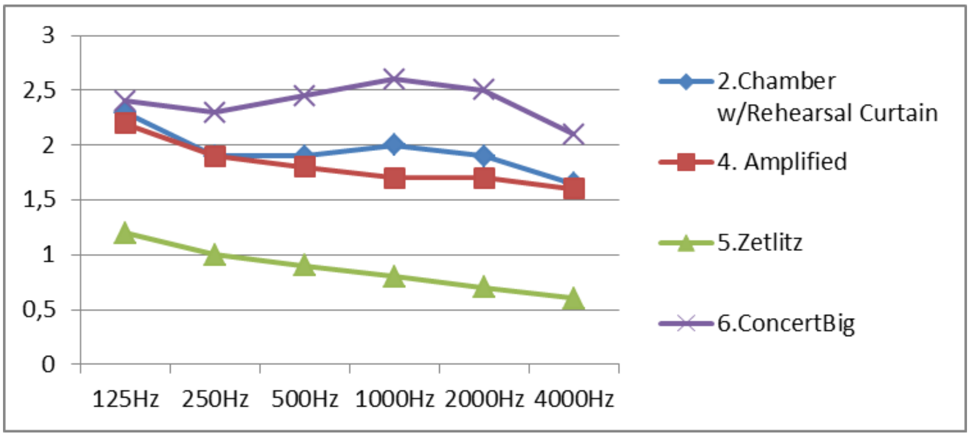
“6. ConcertBig”

Setting for big, acoustic, symphony orchestras.
(Ceiling and canopy reflectors at highest positions). No absorbing curtains.

Symphony Orchestra, minimum 50 musicians



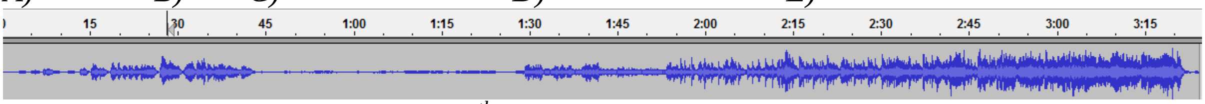
C) MEASURED/STIPULATED REVERBERATION TIMES
T30 [seconds]



The T30 values in this figure are taken from the Acoustic Measurements Report from Kahle Acoustics(Valen) and Akukon (Zetlitz), manually adjusted for the actual settings of the room and the low number of audience (app. 30). (The T30 for Zetlitz is somewhat adjusted for the actual setting of this hall, by analysis of an almost single drum stroke. (See also App.3).

D) MUSIC
The same music of total length app. 3:10 (3:20) minutes was performed four times. Sheet music is shown in Appendix 1.

A) B) C) D) E)



*A) **Trumpet Fanfare** (from Mahler 5th Symph.)*
*B) Added **String Quartet** (from the first part of the orch. score of Mahler 5th.*
*C) **String Quartet a cappella** (adapted/arranged from a somewhat later part of Mahler 5th).*
*D) MM=200. **Jazz/Swing** Piano/double bass/drums + Trumpet 12 bars (a theme based on the Norwegian national anthem, or: since it is a shortened version: "The Norwegian Rational Anthem"). Followed by 10 bars piano ad lib, and 2 bars with trumpet.*
*E) **Rock**: MM=80. 2 bars drum solo (Slow Rock, back beat ad lib) followed by Electric Guitar/6-strings el-bass/drums Trumpet: 12 bars. Followed by 8 bars rock guitar solo ad lib, and 4 bars trumpet lead to fermata coda chord.*

The recording level was kept constant during all recordings. This, of course, gives a very low Signal/Noise ratio for the String Quartet part, but was chosen in order to investigate the dynamic differences between the types of music. Both halls were equipped with Steinway Grand, biggest model in Valen, both tuned to 442 Hz. Trumpet(C-trumpet) and drums were played without any amplification. Double bass/el-bass had his own, close separate amplifier. El-guitar (Gibson Les Paul) with a distortion pedal was equipped with the same type Fender Twin Reverb amplifier in both halls. For practical reasons, el-bass was used both for the Swing Jazz (and Rock) part in Zetlitz. The amplifiers for bass(es) and guitar were exactly the same in the two halls, but there might of course be minor adjustments in both gain and equalisations for these. No use of house PA-loudspeakers. The total session (including the lecture) took about 1 hour 45 min., including quick transport between the settings/halls.

The musicians were instructed that the acoustics of the different settings was the main issue, so they should play as equally in the four situations as practically possible. Minor changes in playing styles etc. for the different settings will of course occur, and some of these were analysed.

The order of the settings/halls were chosen mostly for practical, stage technical reasons, but the first setting *"2.Chamber"* was deliberately chosen to be the first, as this should be a reasonably good choice for a string quartet. In all the discussions in this report, the chronological order of the settings is preserved, in order to be able to judge any changes due to the increased familiarity of performing the music, and, on the other side; any effect of "fatigue".

The trumpeter was familiar with Mahler 5th from his studies (and suggested this piece as the *a cappella* "fanfare"). The string quartet and the trumpet had separate rehearsals before the day of the lecture/performance. The total music programme was tested in setting *"2.Chamber"* 2-3 times before the recordings. The drummer was instructed to play as strong as the styles of music indicated, and not restrict his performance (too much) in the most reverberate settings. The audience area was almost empty, only ca. 30 persons from the IMS conference. (That is why the rehearsal curtain was used for setting *"2.Rehearsal"*). The other settings for the Fartein Valen concert hall were those used by the house for "Amplified Events" and "Concert Big Orchestra". The rehearsal curtain was not used in this last setting, in order to investigate the maximum change of reverberation etc. (knowing that setting *"6.ConcertBig"* could be "too much" for these actual instruments/ repertoire).

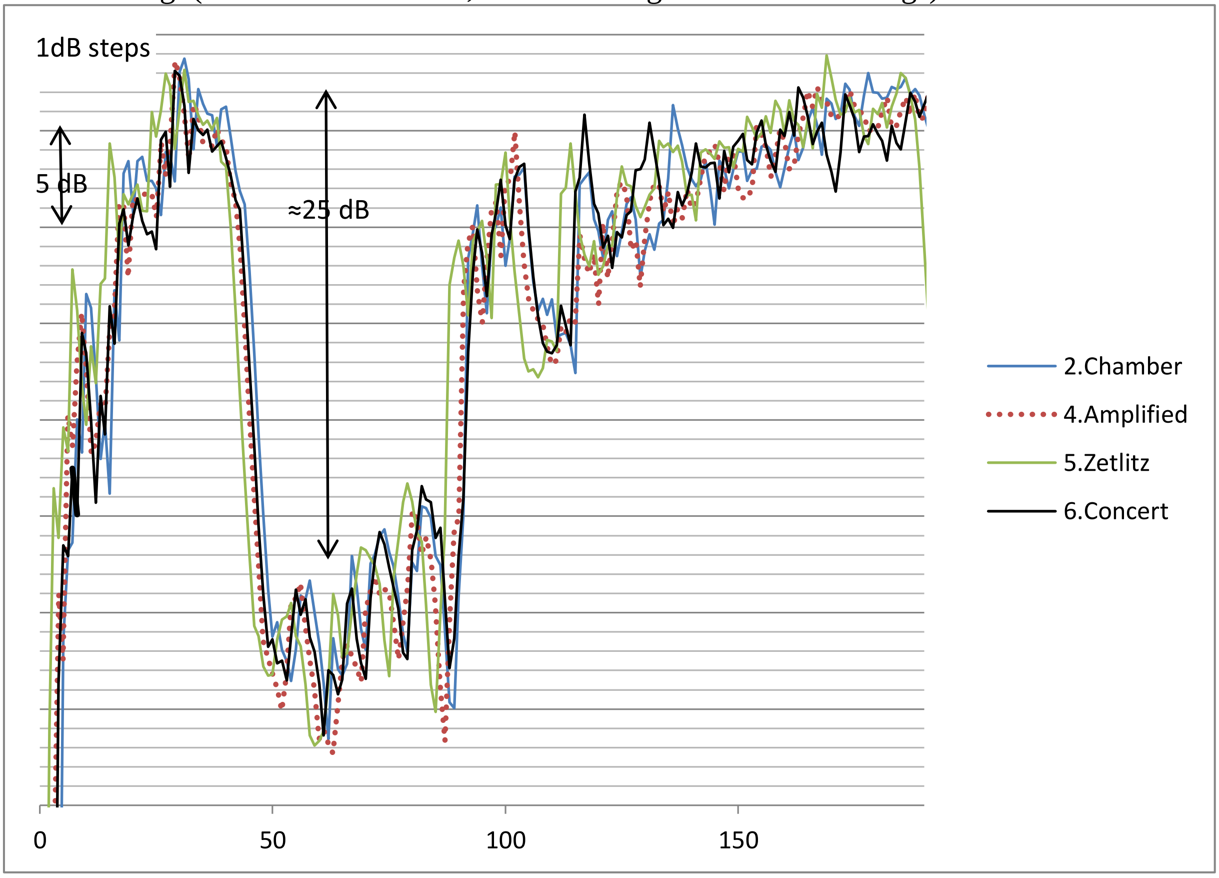
The jazz and rock parts were (somewhat) improvised (except the trumpet part), in order to get a typical performance, so there will of course be differences in the material for the different settings. All music was played without any metronome, (so differences in tempos might be analysed).

E) OVERALL ANALYSIS OF THE RECORDINGS

E.1) STRENGTH
Relative values
(0=setting *"6.Concert"*)

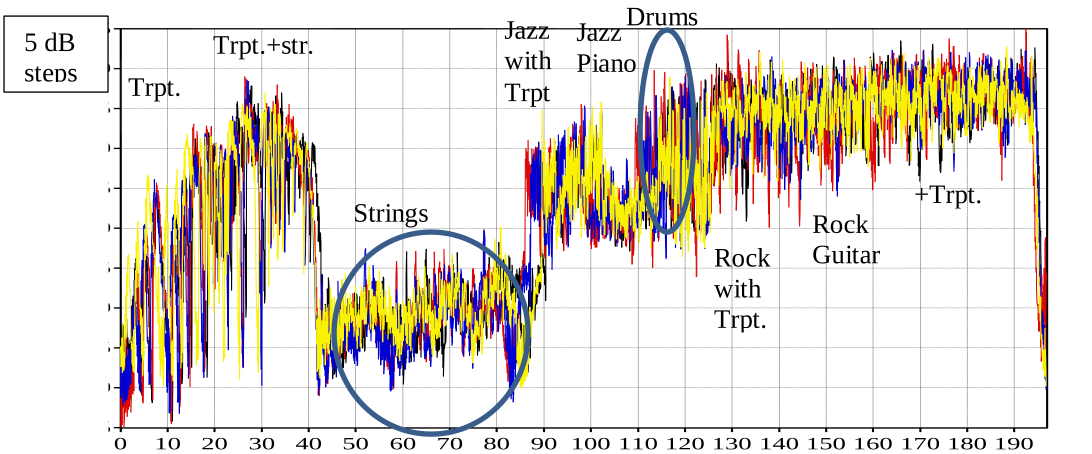
	RMS (MIR toolbox)	***dB, Mean (from Praat)***	*dB, Max (from Praat)*	**Leq** [dBA] (from ARTA)	**LC,peak,** [dBC] (from ARTA)
2.Chamber wCurtain	0.34217	**-0.24**	2.06	**0.80**	**1.80**
4.Amplified Setting	0.33237	**-0.23**	-1.02	**0.00**	**-0.30**
5.Zetlitz:	0.32116	**0.00**	-0.71	**0.50**	**0.20**
6.Concert Big	0.32816	**0.00**	0.00	**0.00**	**0.00**

1s smoothing: (not calibrated 0-leve, but constant gain for all recordings)



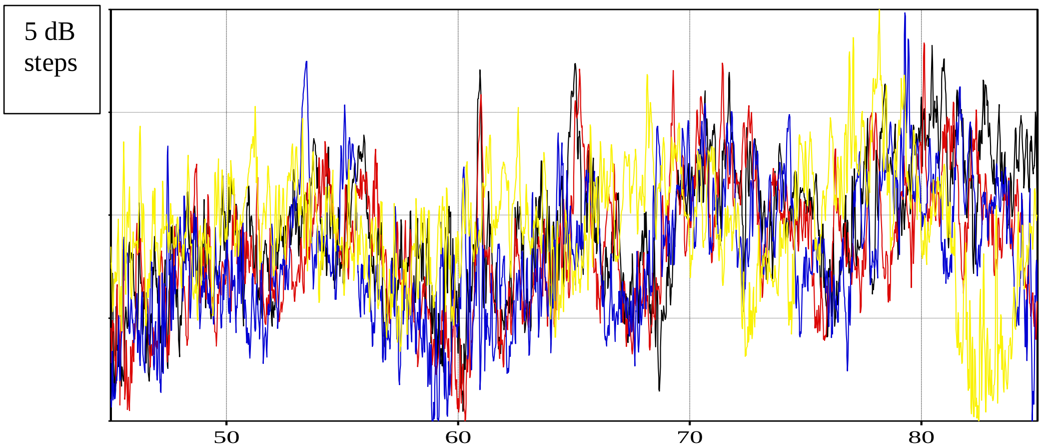
We see the following Dynamics:

Trumpet solo/String Quartet:	ca 25dB
Rock (without trpt.)/String Quartet:	> 25 dB

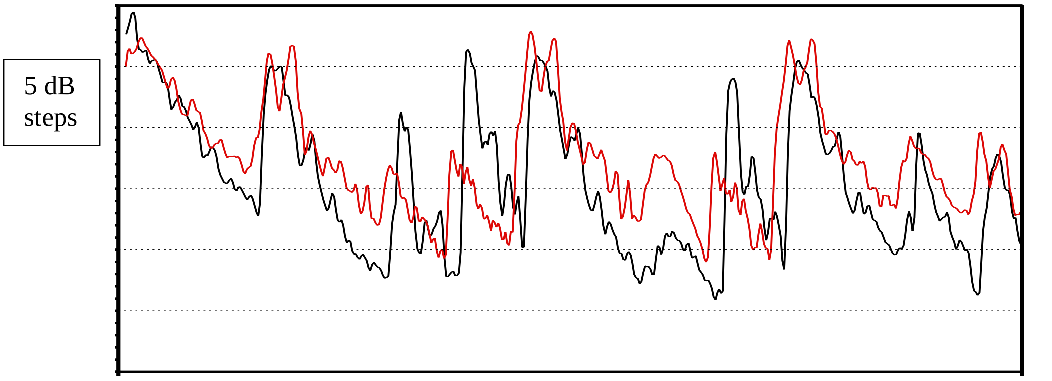


Red=*"2.Chamber"*, Black=*"4.Amplified"*, Yellow=*"5.Zetlitz"*, Black=*"6.Concert"*
(Time adjusted to match *"6.Concert"*)

Zoom in on Strings part:



STRENGHT DRUMS SOLO, first 4 seconds:
Black= *".5.Zetlitz",* Red= *"6.Concert"*



"6.ConcertBig" (Red) shows somewhat stronger peaks (2-3 dB?) than for *"5.Zetlitz"*, with longer decays, and the decays do not get as low in dB as for «*5.Zetlitz*», probably due to the masking long delays in the reverberant *"6.ConcertBig"*. There is a tendency that also the attack times are longer in the reverberant *"6.ConcertBig"* (discussed/measured later).

E.2) STRENGHT COMPARED TO G[dB] MEASUREMENTS IN VALEN

The Valen hall has free hanging side-balconies with "downstands" (see App.2). A wanted effect of this is that the Acoustics Measurements Report shows that the early strength (G,early) changes just 0.1 dB when changing from a dampened hall to a fully reverberant setting. The late reverb, however, changes increases some 1.6 dB from a setting comparable to *"2.Chamber"* to *"6.ConcertBig"*. These G measurements are in good agreement with the almost 0 dB change found in E.1 from the recordings. (0.0 to 2.0 dB, with the highest values for the "peak sounds"). The "almost zero" change of strength for the "mean" and Leq values in E.1. might indicate a slight "compensation" from the musicians, meaning that they play somewhat softer in the most reverberant setting (*"6.ConcertBig"*). (Earlier measurements in music rehearsal rooms show a bigger compensation, see Halmrast: *"Musician´s Perceived Timbre and Strength in (too) Small Rooms"*).

Unfortunately, we do not have G-measurements for Zetlitz.

E.3) FREQUENCY SPECTRUM (for the entire length of music)

We see that the spectre is almost the same for all settings! However, Zetlitz gives a somewhat higher "brilliance".

E.4) SPECTRAL CENTROID

Spectrum Centre of Gravity, (Praat, Power=2 (standard) ("Spectral Centroid") was measured from the recordings of the entire music. In the second column, this is compared with the spectre of the reverberation time versus frequency (from the T30 values in the figure on p. 5). This is of course a "non-traditional" parameter, which might be called "Spectral Centroid of Reverberation Time" (linear frequency).

	Sp.Centroid	**"Sp.Centroid of RT"**
"2.Chamber w/rehearsal curtain":	709 Hz	865 Hz
"3.Amplified":	727 Hz	853 Hz
"5.Zetlitz":	823 Hz	729 Hz
"6.ConcertBig":	720 Hz	907 Hz

The two parameters are of course not directly comparable, but we see that that the columns show opposite trends. From the recordings, Zetlitz includes less reflections/reverb, more "direct sound", and shows a higher amount of treble. From the reverberation time measurements, the big, non-dampened Valen shows the most "brilliant" reverberation time. (PS! The flexible absorbers in Valen are curtains, so the damping is mainly for mid-/high frequencies). This comparison **indicates that the amount of reverberation might influence the reduction of "brilliance" more than the actual reverberation time versus frequency.** This might indicate that **adding reverb will reduce high frequencies (also when the reverb has a (moderate?) increase of reverberation for high frequencies)**. (This is of course somewhat analogue to how pass filters are made, taking the mean of several delayed samples, like a "smoothing" of the signal).

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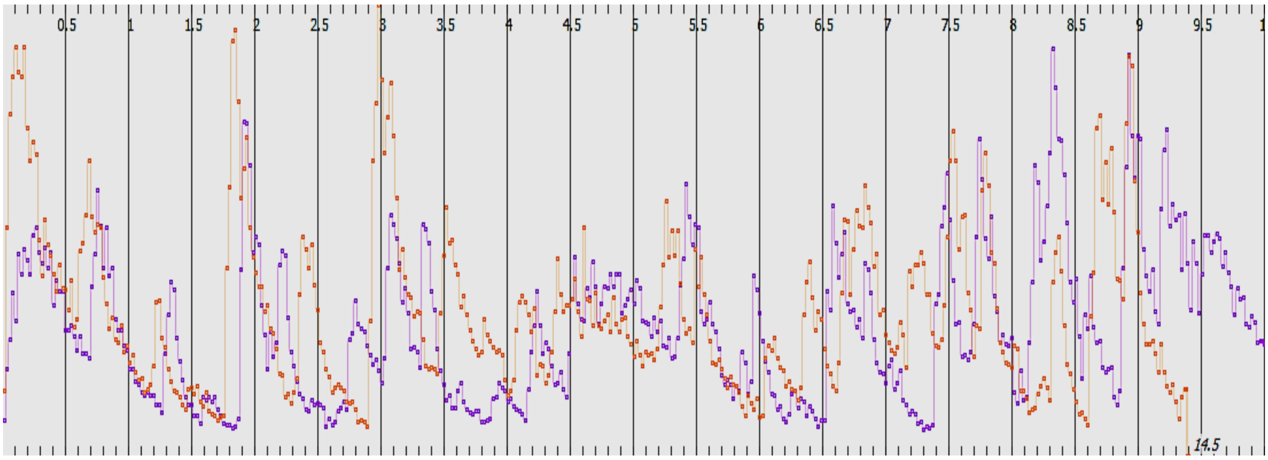
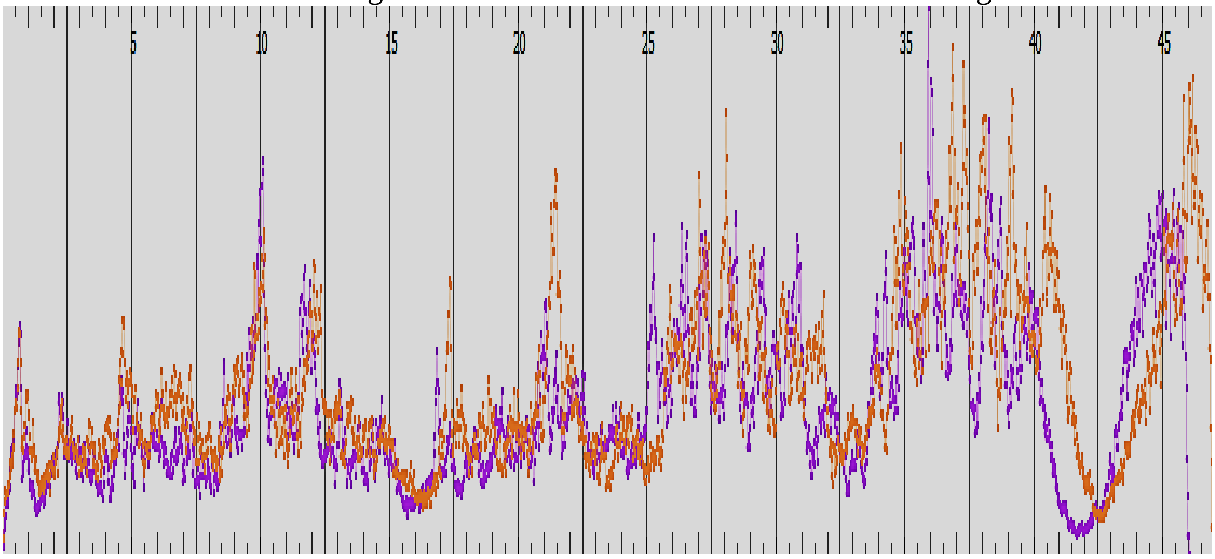
DRUMS SOLO, Spectral Centroid over time
Blue = *“4.Amplified”*
Orange = *“6.Concert”*



For the first part it seems like the longer reverberation in *“6.ConcertBig”* gives a higher spectral centroid, but this is the opposite for the late part. As the drum part is somewhat improvised, this measurement might of course not be significant.

The following figure shows the Spectral Centroid, for the STRING QUARTET which plays the same notes in both settings. The colour code is the same as for the last figure:



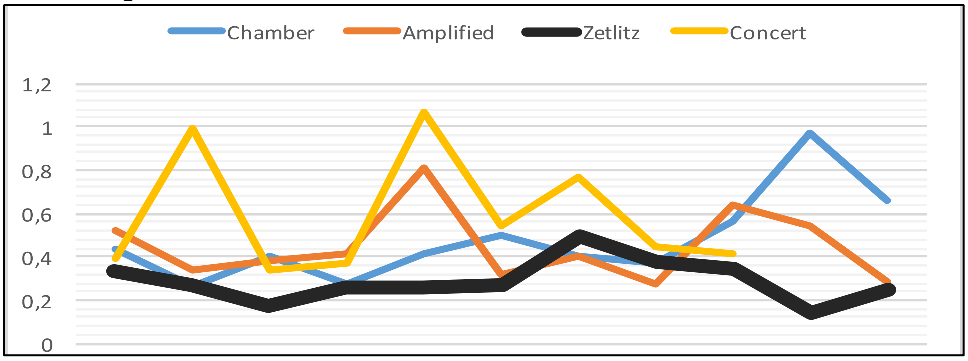
This measurement might indicate a higher Spectral Centroid for the *“6.ConcertBig”* setting than for the *“4.Amplified”* more “dry” acoustics of the Valen hall.

This might indicate that the slow “build up” of the tone for string instruments (see App. 5.2) gets more benefit from the longer reverb.

F) NOTE-LENGTH

F.1) NOTELENGTH DRUMS SOLO

The MIR toolbox parameters "mirNotelength" (and "mirattack/release") was investigated, but showed invalid results of minor interest for parts with more than one voice, even after filtering the recordings ("mirfilterbank"), probably because the algorithm has problems detecting each attack correctly. For the 2-bar Rock with drums solo, the result was somewhat more interesting:



≈45 sec.

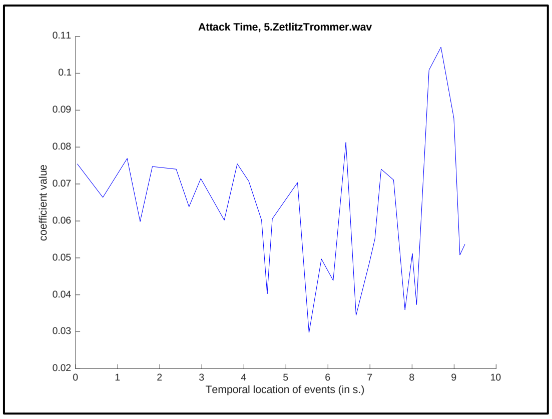
Median: (Tone length, drums solo)
(start and end note of the drums solo skipped, due to overlap by other instruments)

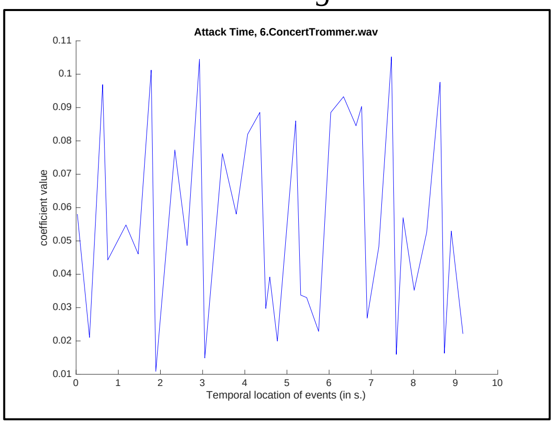
2. Chamber	***4.Amplified***	***5.Zetlitz***	***6.Concert***
0.41	**0.40**	**0.27**	**0.44**

There are still some uncertainties regarding if "mir" finds the actual attacks, but the main result is that the note lengths are clearly shorter for "*5.Zetlitz*". It is also reasonable that *"2.Chamber"* is slightly higher than *"4.Amplified"*, and that *"6.ConcertBig"* shows the longest note length. In general, however, the parameter "mirnotelength" does not give exact information about what is happening regarding note length, and we need to inspect the recordings more in detail.

F.2) ATTACK TIME; DRUMS SOLO (mir toolbox)

«5.Zetlitz» *«6.ConcertBig»*





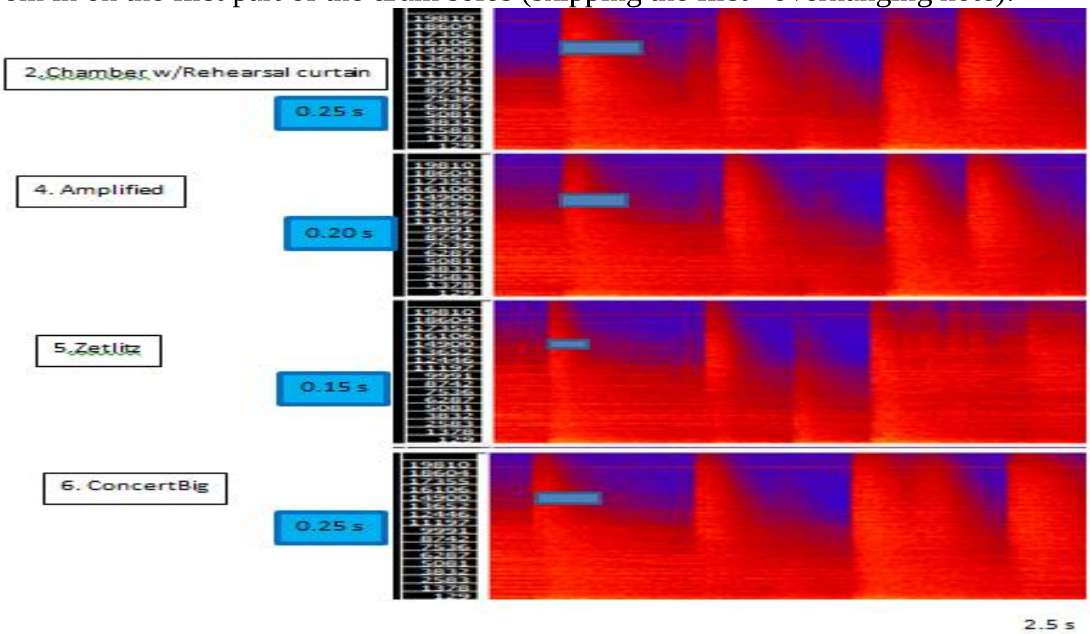
The attack time is longer in the reverberant *«6.ConcertBig»* than in *«5.Zetlitz»*. (Apart from the very last stoke(s) which must be due to different performance).

Unfortunately Mir Toolbox did not manage to detect and analyse the attack of each instrument for the String Quartet and jazz/rock, so the "mirattack" did not show reliable results for polyphonic parts (even after filtering using "mirfilterbank").

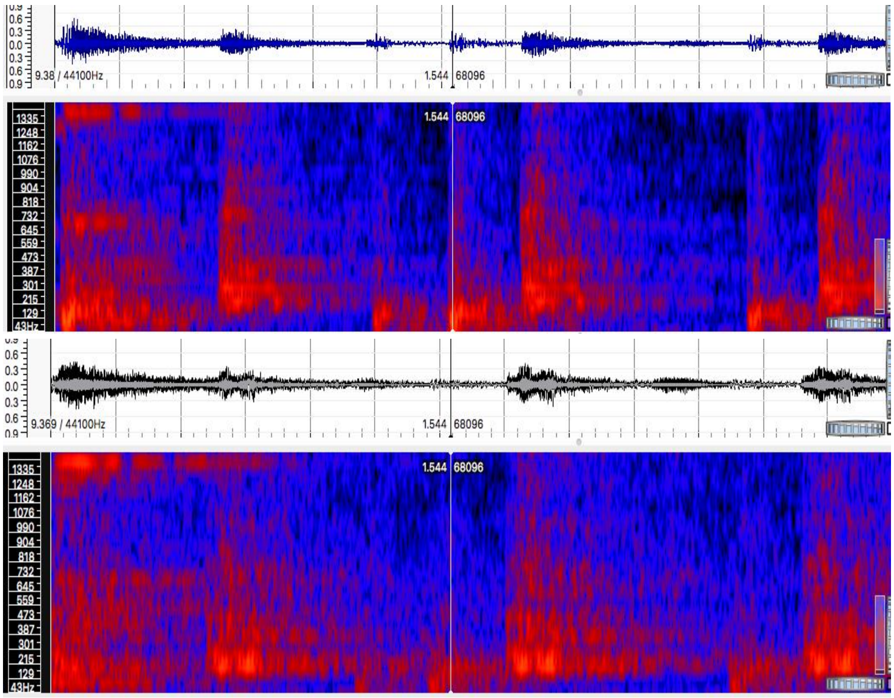
F.3) NOTELENGTH DRUMS SOLO from Spectrogram

The exact length of each tone shown in spectrograms is, of course, dependent on the FFT-window (and the Gain for the colours), but since this (and the other settings) were the same for both analysis, we can inspect the relative lengths.

Zoom in on the first part of the drum solos (skipping the first «overhanging note):



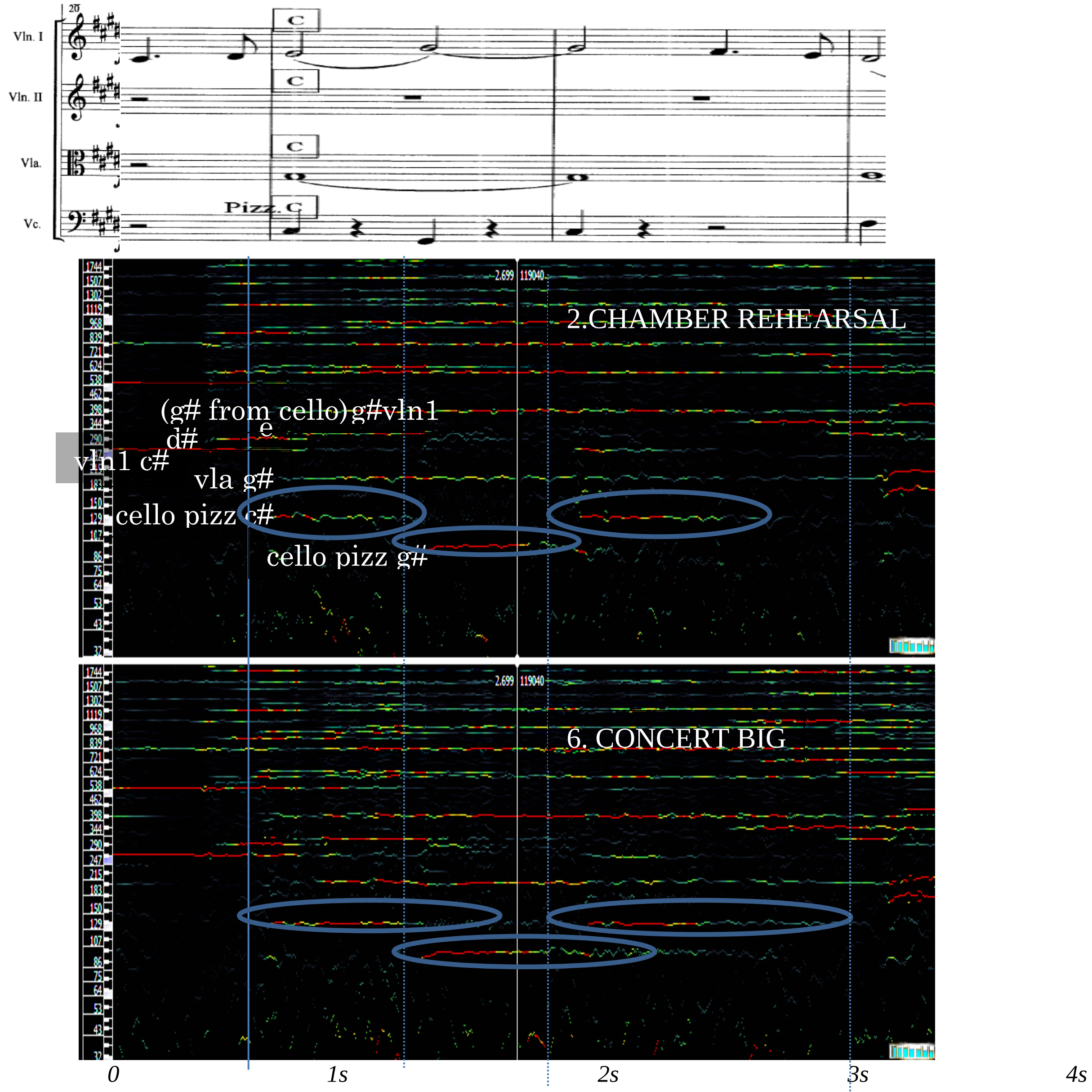
First part of DRUMS SOLO (Melodic Range Spectrogram):
Upper Curve: *"5.Zetlitz"*, Lower Curve: *"6.ConcertBig"*



This analysis clearly show longer decay in the reverberant *"6.Concert"*, and also longer/softer attack!! Each beat appears to be almost 0.5 s longer.
PS! The first note is probably an overhanging tone from trumpet in the earlier swing part.

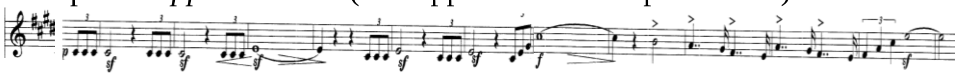
F.4) NOTE-LENGTH STRINGS
Peak Frequency Spectrogram:
Upper: *“2.Chamber w/RehearsalCurtain”*
Lower: *“6.Concert Big”*

Tempo half note, MM 𝅗𝅥=60

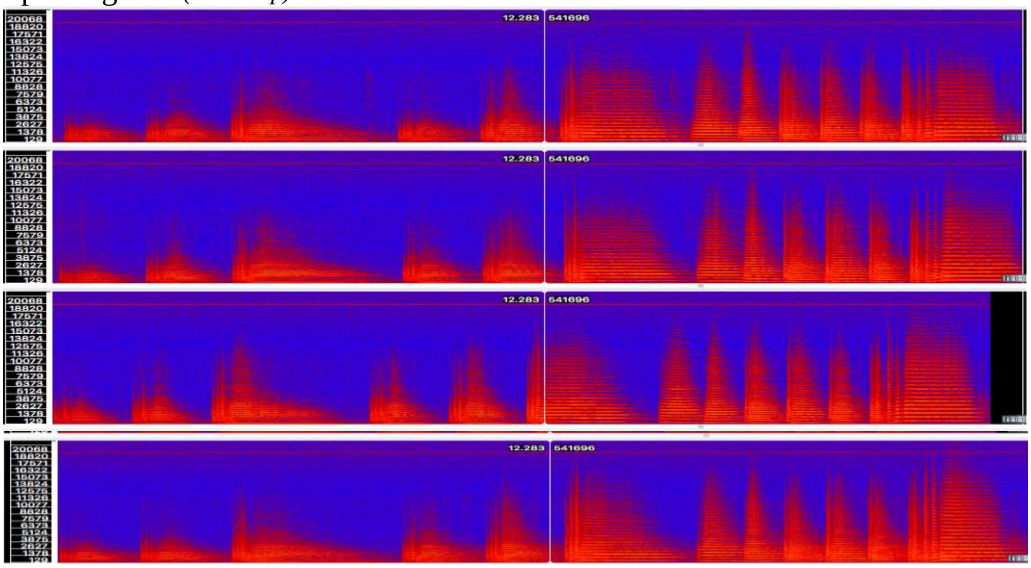


For the chosen setting of Gain and FFT-window for this spectrograms, the length of the cello pizzicatos (C#s and G#s) are shown to be about 50% longer in *“6.ConcertBig”* compared to *“2.Chamber”*. In *“6.Concert”*, strings are perceived to be stronger, more «round», because they are longer, even if the spectral centroid etc. does not show that much difference (see also App. 5.1).

F.5) NOTELENGTH TRUMPET *a cappela*, start, fanfare.
The trumpet is of course difficult to analyse, because it is difficult to distinguish between the actual performed tone length and the decay. However, the following figures show the start of the trumpet *a cappela* fanfare (see App.1 for the complete score):

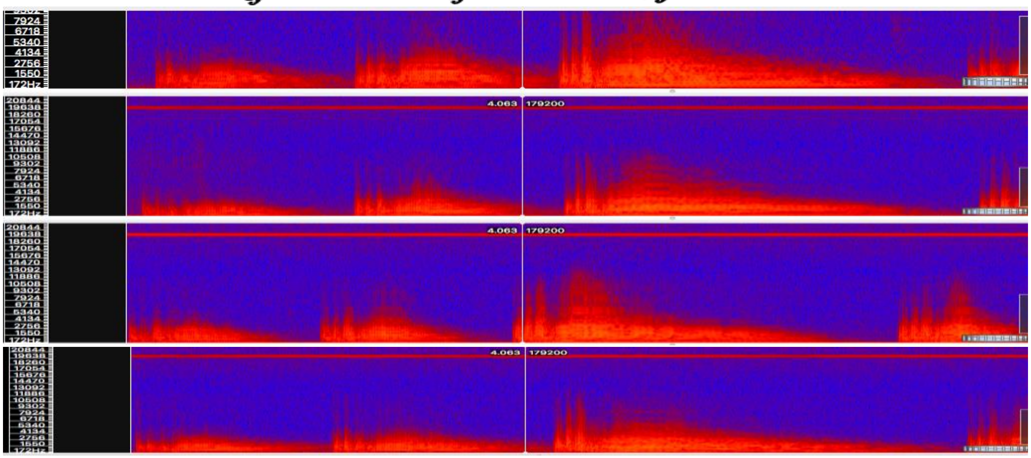


Spectrogram: *(0 overlap)*



0 sec *24 sec.*

Zoom in from start:



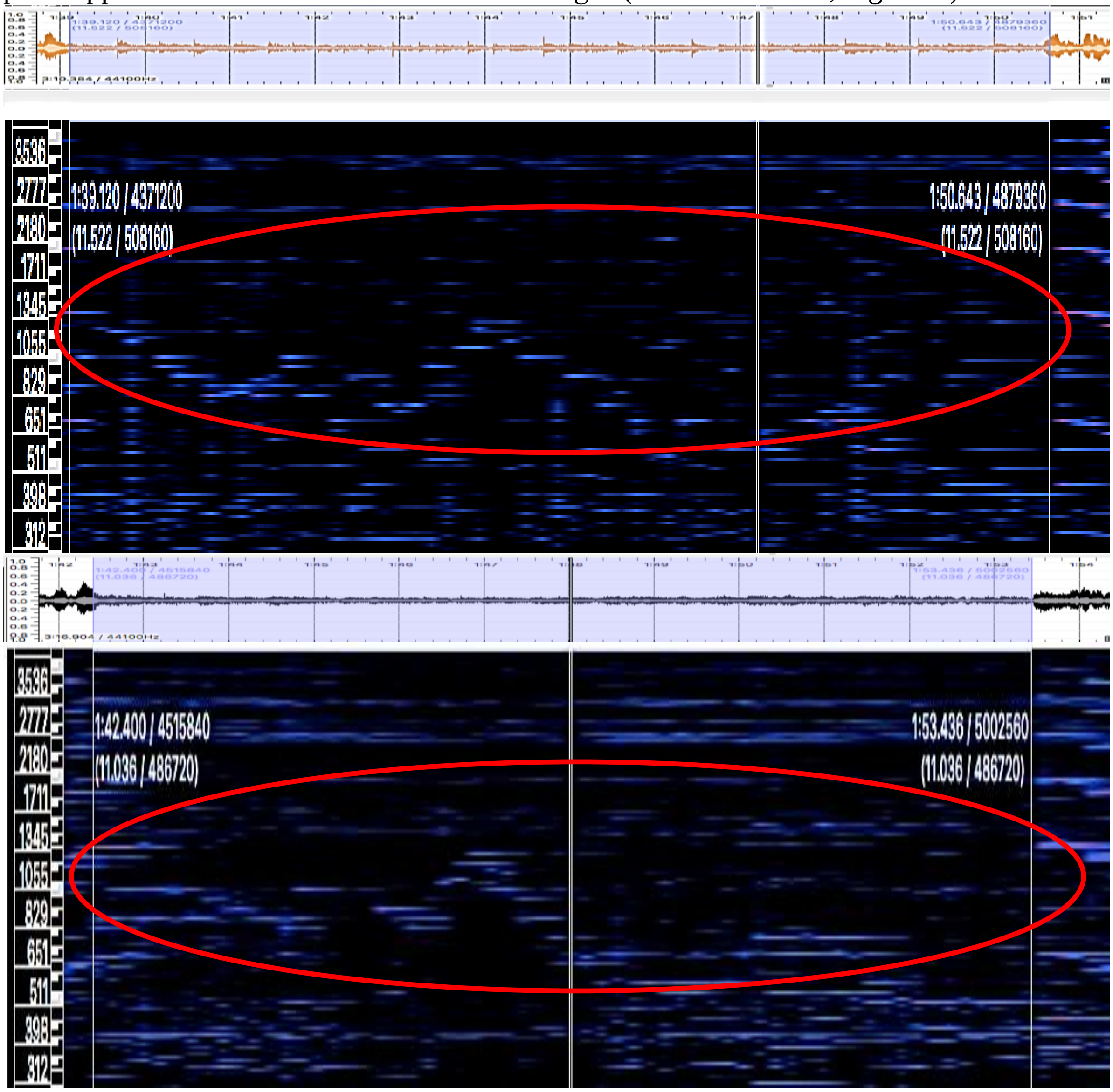
0 sec. *9.5 sec*

We see that all the decays are all longer in Valen. (The fact that the decay seems longer in *"2.Chamber"* and *"4.Amplified"* than in "*6.ConcertBig"*, might be an artefact because this overall sound pressure for the trumpet part was somewhat lower in *"6.ConcertBig*.

It might be noticed that that the very shortest tones in *"5.Zetlitz"* seems longer than for the other settings. This is the trumpeter´s way of compensating for the lack of reverb in *Zetlitz.* The trumpeter clearly commented on the difficulty of playing the *a cappella* fanfare in the short reverberation in Zetlitz. Additional discussions about Note Lengths are given in App 5.

F.6) NOTELENGTH JAZZ PIANO

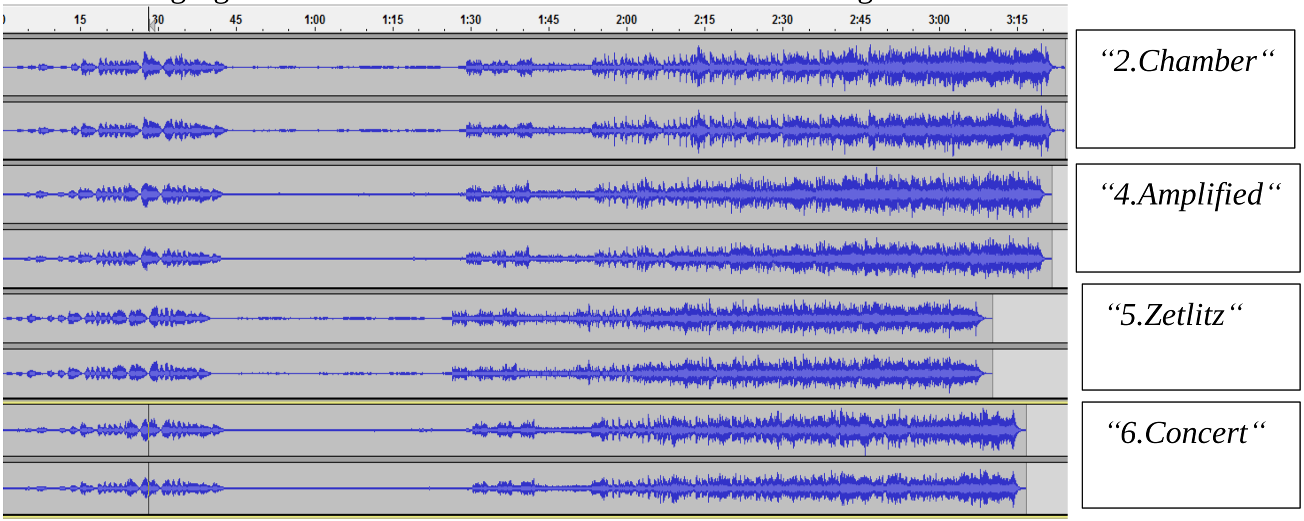
The following figure shows the spectrogram of the piano improvisation part of the swing jazz part. Upper= *"5.Zetlitz"*. Lower= *"6:ConcertBig"*. (ca. 300-4000 Hz, log scale)



We see that for the **jazz piano** parts, the **prolonged decay of the most reverberant settings will "mask" the following (also prolonged) attack. This is the main reason for the "timbral" change clearly perceived both in the halls and listening to the recordings.** (Unfortunately, the mir-programs were not able to detect each attack/delay for the jazz piano part when the bass+drums were playing).

G) TEMPO

The following figure shows the entire waveforms of the four settings:

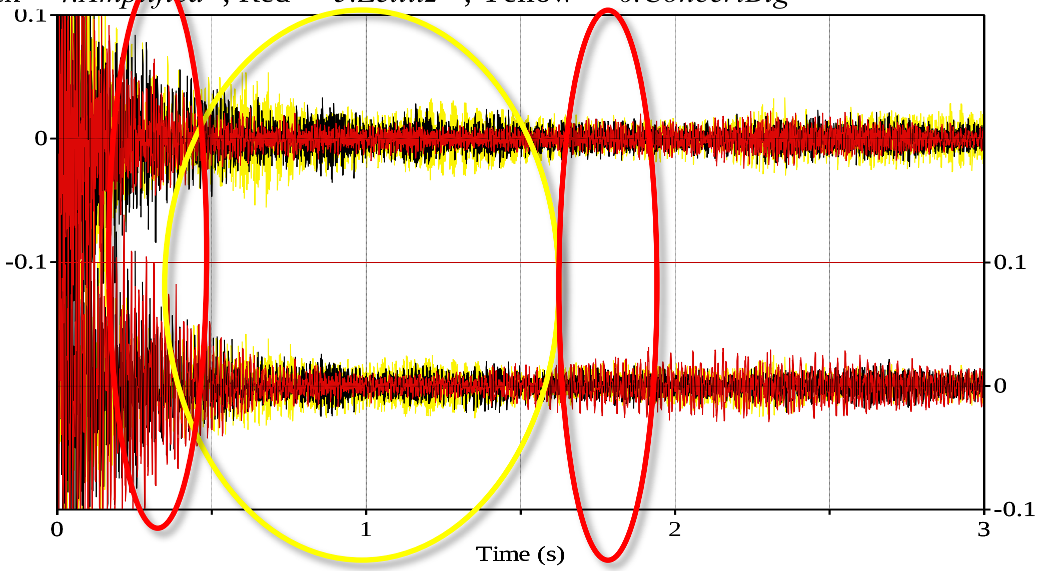


We see that the Tempo is highest in *"5.Zetlitz"* (with the shortest reverberation time). The tempo in *"5.Zetlitz"* is ca. 5% faster than in *"2.Chamber"*. (ca. 190s compared to 200s). (PS! Note that the start is not exactly the same for all recordings). The trumpet plays his fanfare-intro faster in the "dry" Zetlitz. He reported much more problems regarding lack of "feedback" from this room. (These "problems" regarding performance are actually shown in the details of the recordings). The fact that the tempo is high also for *"6.ConcertBig"* is surprising, as this is for the longest reverberation time. The reason might probably be that this was the last recording before "going home", or that the faster tempo from Zetlitz was "still in the blood" of the musicians.

H) AUTOCORRELATION

Using Praat we get this results:

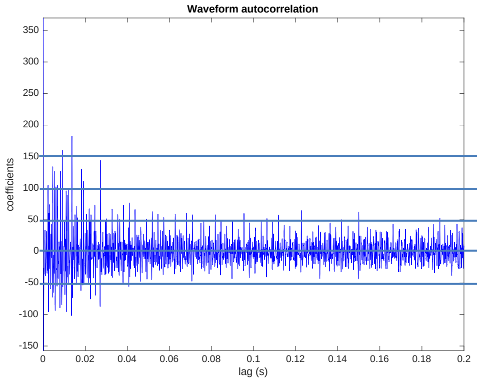
Black=*"4.Amplified"*, Red= *"5.Zetlitz"* , Yellow= *"6.ConcertBig"*

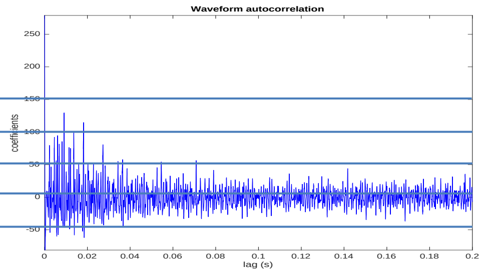


The differences are not big, but this analysis using Praat indicates that the most reverberant setting (*"6.ConcertBig"*, yellow) has the highest autocorrelation for "time lag" ("tau") around 0.6s-1.4s. The "dry" *"5.Zetlitz"* seems to have the highest autocorrelation for time lags around 0.5s and ca. 1.5s.

Using “mirautocor” for shorter time (“time lag” to 0.2 s) we get the following results for Autocorrelation:

“5.Zetlitz” *“6.ConcertBig”*

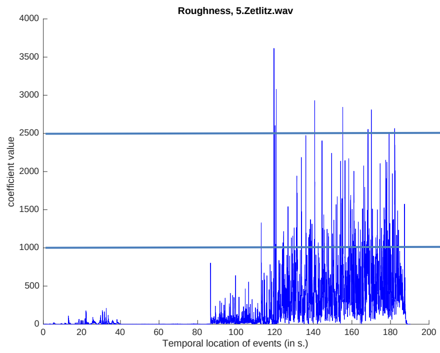


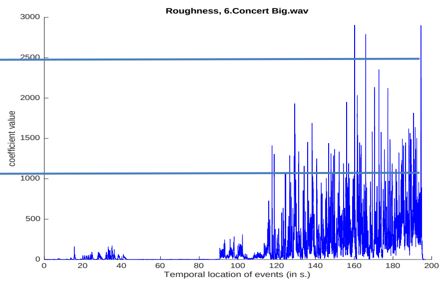


These “mirautocorr” shows that the Autocorrelation for the first 0,2s “time lag”/”tau” is higher in *“5.Zetlitz”* than for *“6.ConcertBig”*. This might indicate that the non-correlated reverberation in dominates much earlier in Valen than in the dry Zetlitz. Autocorrelation of recordings from concert halls should be further investigated.

I) ROUGNESS

Listening to the performance in the different settings (and to recordings) indicates that the reverberant settings (like *“6.Concert”*) sound “smoother”. The problem is to find a parameter that shows this. As a test, we calculated the mirroughness. This parameter indicates sensory distance, related to the beating phenomenon wherever pair of sinusoids are close in frequency (related to Critical Bandwidth). The parameter “mirroughness” computes the peaks of the spectrum and takes the average of all the dissonances between all possible pair of peaks.





We see that the Roughness is higher for “5.Zetlitz” than for “6.Concert”, especially for the last part of the performed music. This might of course just be due to the different improvisation, especially for the distorted guitar. However, there seems to be a slight reduction of roughness also for the first trumpet and trumpet+strings section. Roughness is by no means a parameter commonly used for analysing “smoothness”, and this analysis was just a “blind shot” to check if “mirroughness” (or any other MIR-parameter) could be used for this purpose.

J) BINAURAL PARAMETERS

In Fartein Valen the amount of Lateral Reflection is measured to be high, higher than many comparable halls. The recordings of the performances were not at all binaural. However, we might get an idea about the "stereo-width" analysing the *cross correlation* between the 2 microphones on the top of the Zoom recorder:

"IACC" (Between mics, not binaural):

"2.ChamberDrumsSolo"	0.8992
"4.AmplifiedDrumsSolo"	0.8870
"5.ZetlitzDrumsSolo":	0.9168
"6.ConcertBigDrumsSolo":	0.8549

The measurements in the Acoustic Measurements Report (Kahle Acoustics) for Valen used a version of "1-IACC" (1-IACC,0-80ms), which was measured to app. 0,65 (for the "main configuration", giving a IACC, 0-80ms of 0.35. It is natural that our simplified "stereo" recordings give higher correlation between the two ordinary microphones on top of the hand held Zoom recorder, compared to the correlation between the ears on each side of your head or correct binaural recordings, so the exact numbers from our "almost IACC" measurements are not that interesting. However, we can compare our different settings, and we see an increased "envelopment" (lower correlation) in Valen (*"6.ConcertBig"*) compared to the dampened Zetlitz and the less reverberant setting of Valen (*"2.Chamber"*).

K) END NOTE

Both musicians, audience and people who listened to the recordings appreciated the excellent and highly flexible acoustics of Stavanger Concert Hall. The settings used in this test were chosen in order to hear and investigate the room acoustics extremes. The setting *"2.Chamber"* was appreciated both for trumpet solo and the string quartet. For jazz and especially rock, the much less reverberant *"5.Zetlitz"* was clearly the favourite, with *"4.Amplified"* as a reasonable substitute. The setting with the longest reverberation time and the largest room volume, *"6.ConcertBig",* was included for the test, but was much too reverberant for jazz and rock, and also "a bit too much" for trumpet solo. In this test, with the extreme dynamic changes between jazz/rock/trumpet and the string quartet, the last setting was perceived as "perhaps good, probably Too Much" for the string quartet, and *"2.Chamber"* was a better choice. This shows that the design of the halls fulfil the demanding brief for the project.

"Med klangfull hilsen!"

Tor Halmrast

App.1) MUSIC/SCORE
App.2) FARTEIN VALEN CONCERT HALL
App.3) ZETLITZ HALL (Multipurpose hall)
App.4) NOTELENGTH. ADDITIONAL MEASUREMENTS
App.5) THE INFLUENCE OF REVERB ON TIMBRE AND ATTACK/DECAY
- *App.5.1) Guitar. Electronic Reverb and Convolution*
- *App.5.2) Cello, Convolution*

APPENDIX 1) MUSIC/SCORE

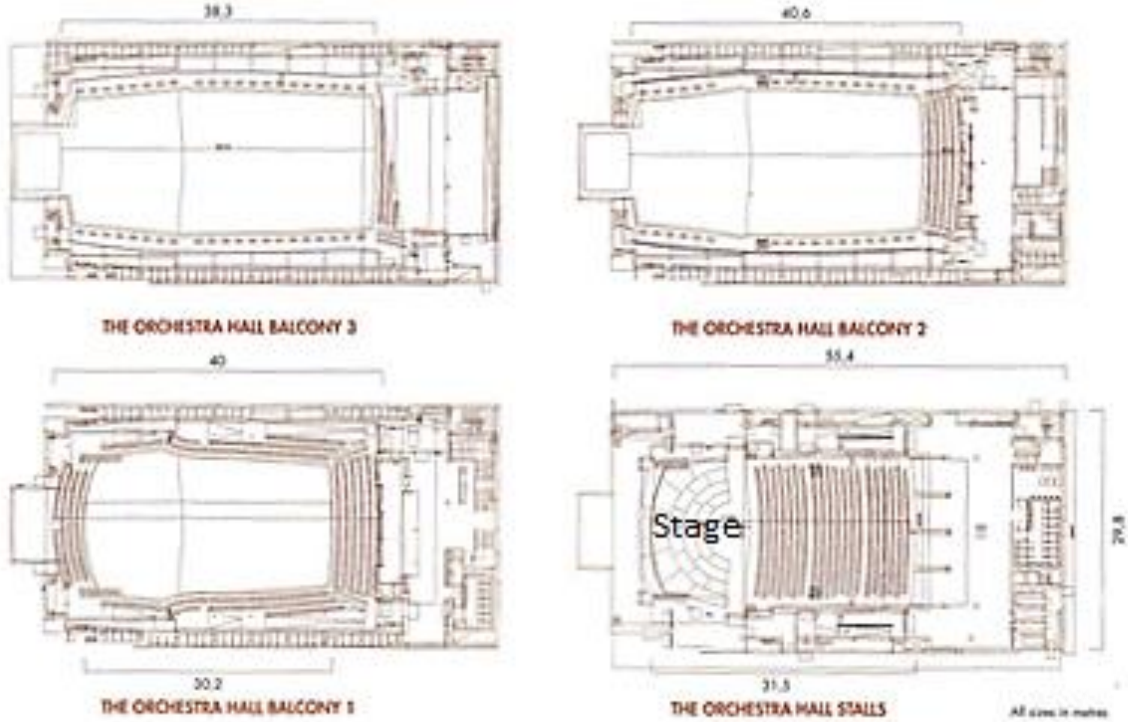
IMS Mahler5 +

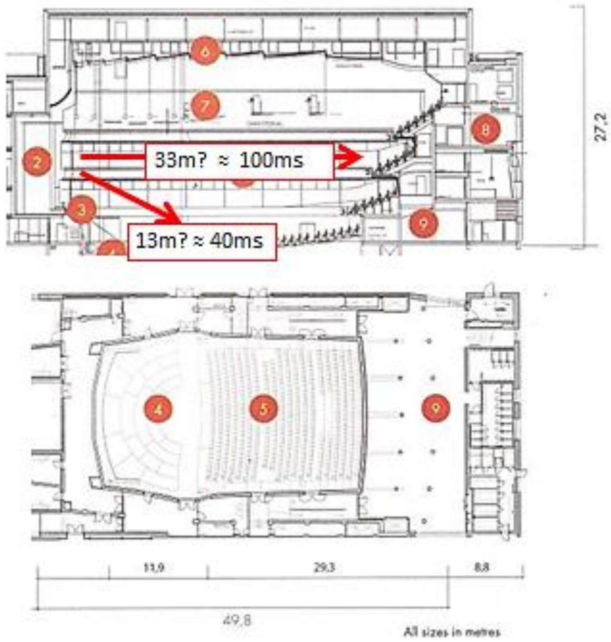
Trauermarsch. *In gemessenen Schritt. Streng. Wie ein Kondukt* arr: TH

Ja,vi elsker jazz/rock

Arr: Tor Halmrast

APPENDIX 2) FARTEIN VALEN CONCERT HALL





"FREE HANGING BALCONIES"

combining the advantages of a relatively
- **small acoustic Width** and of a
- **larger acoustic Volume**

Walls and Balcony fronts: *Maple (oiled),*
Rear wall on stage:
Transparent (often textile behind: percussion)

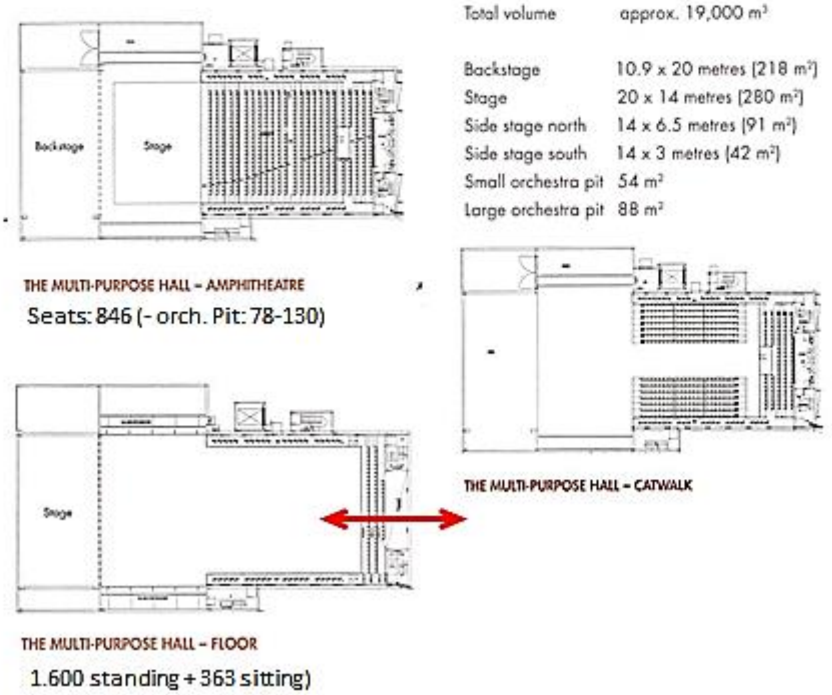
Floor: *Ash NB! VIBRATING UNDER DOUBLE BASSES*

App. 1500 Chairs: *Italian, Maple/mohair.*
Absorbing only under seated person.
Not equivalent to seated person

Downstands

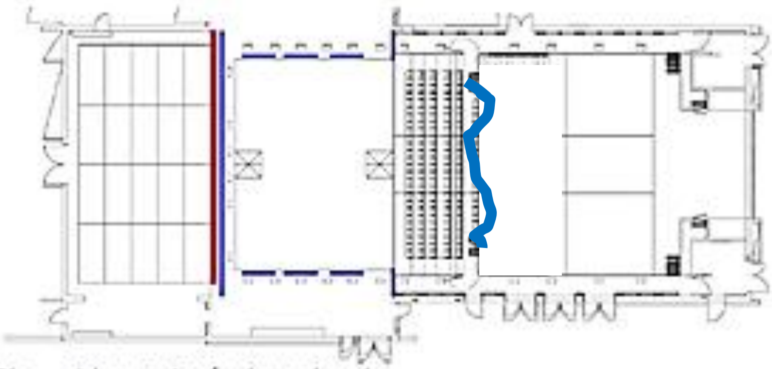
Maximizing energy 0 to 80ms time
→clarity,
Large amount of energy arriving later than 150ms
→reverberance without harming clarity
(better separation between source and room presence).
Downstands define the acoustic width of the hall
→good clarity and
→envelopment

APPENDIX 3) ZETLITZ HALL (Multipurpose hall)

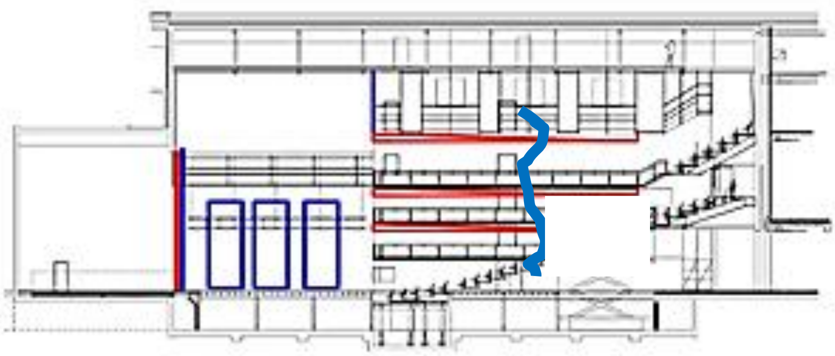


Approximate setting of *"5.Zetlitz"*:

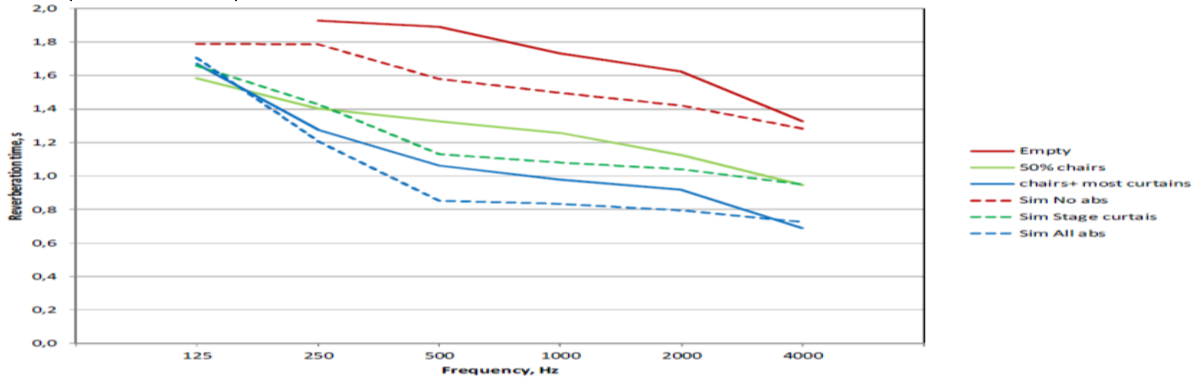
Curtain on stage and on balconies. Small Bleecher audience area (telescopic "amphi") with big curtain closing off the rear part of the audience area. Result is a hall even more dampened than the settings measured by Akukon.



Plan, with curtains for brass band

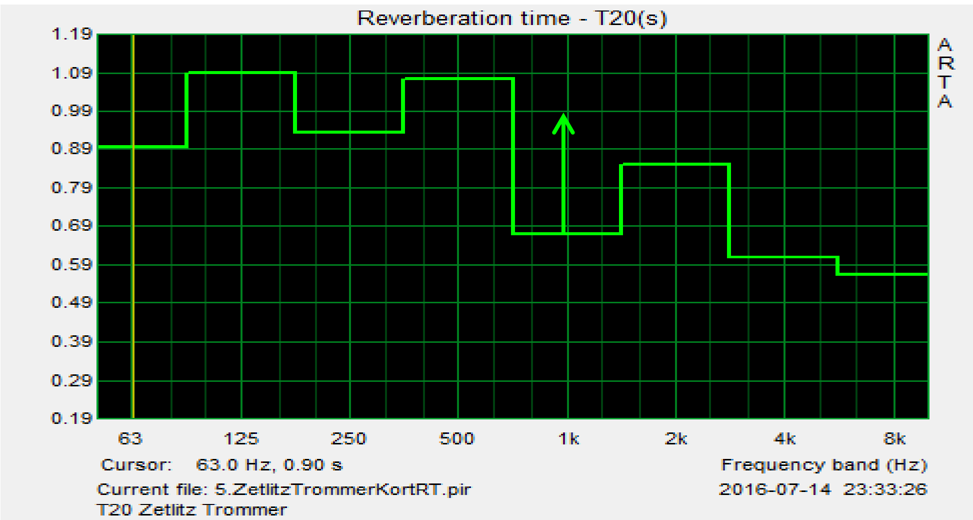


Acoustic Criteria:
REVERBERATION TIME
(middle frequencies, 500-1000 Hz):
Flexibilty:
0,8 s (max dampened)
1,4 s (acoustic hall)



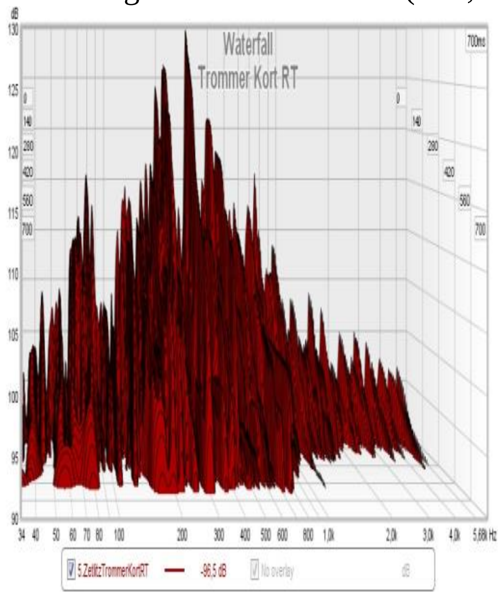
Our setting, "5.Zetlitz" has nor been measured, but stipulated reverberation time (also somewhat adjusted from the following analysis of an almost separate drum stroke.

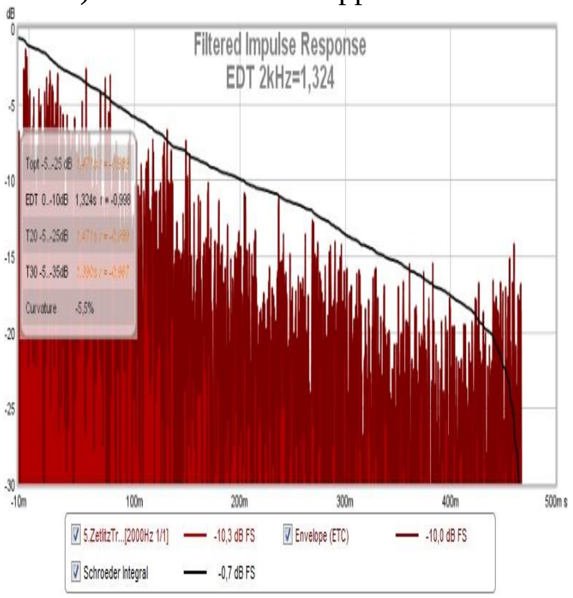
REVERBERATION TIME ZETLITZ (From almost single drum-stroke)
As this was supposed to be a check on the MIR-parameters way of analysing running music, we (unfortunately) did not record any distinct single impulses (like handclaps, balloons or tongue drops). For "real" measurements of reverberation times, confer the Acoustic Measurements report for Fartein Valen from Kahle Acoustics. These measured values are adjusted for the overall figure in this report. As the actual setting of Zetlitz is not measured (by Akukon), we performed some (unreliable) analysis of an "almost single drum stroke" from the drum solo in Zetlitz.

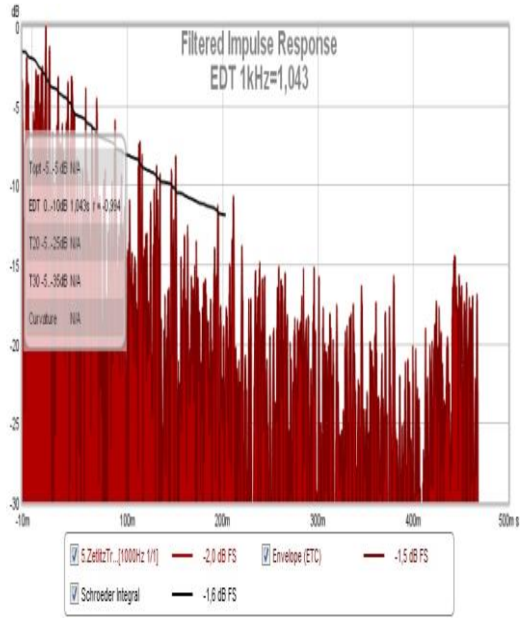


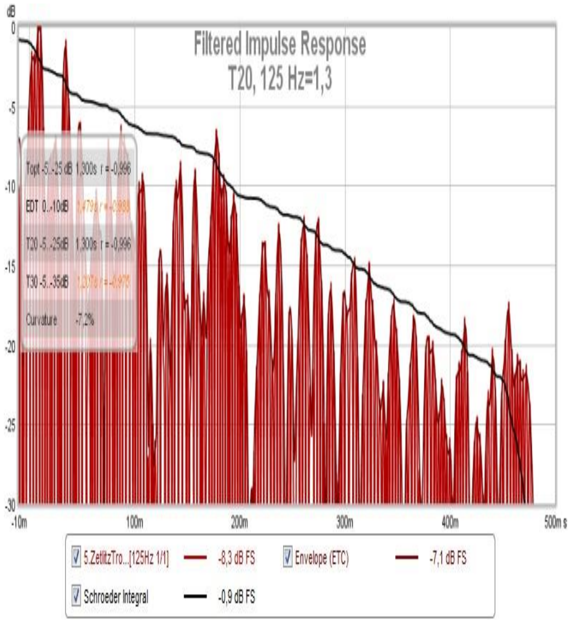
DECAY OF DRUM STROKE IN ZETLITZ

Analysis using the REW5 program shows that the decay is (of course) not really good for reverberation analysis (as there is not a distinct impulse, but just an almost single stroke on the drums, which have their own "decay"/"reverb"). The REW program has problems calculating reverberation times (T30, T20 etc.). The EDT values appear to be somewhat high.





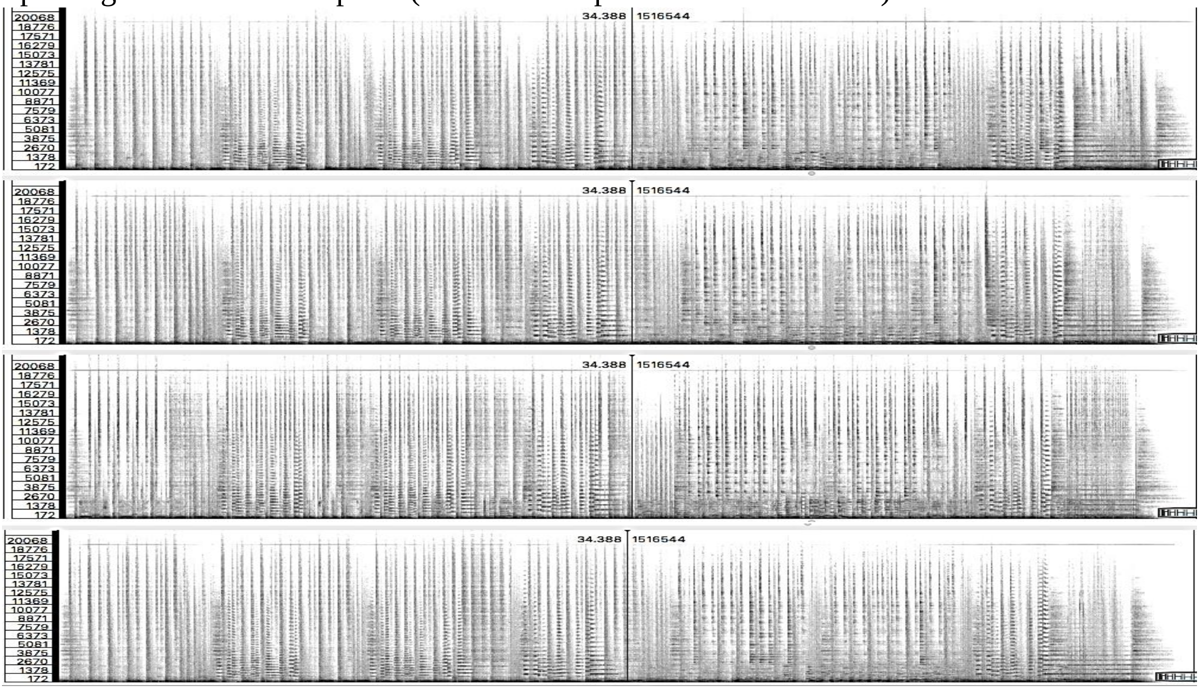




APPENDIX 4) NOTELENGTH, ADDITIONAL MEASUREMENTS

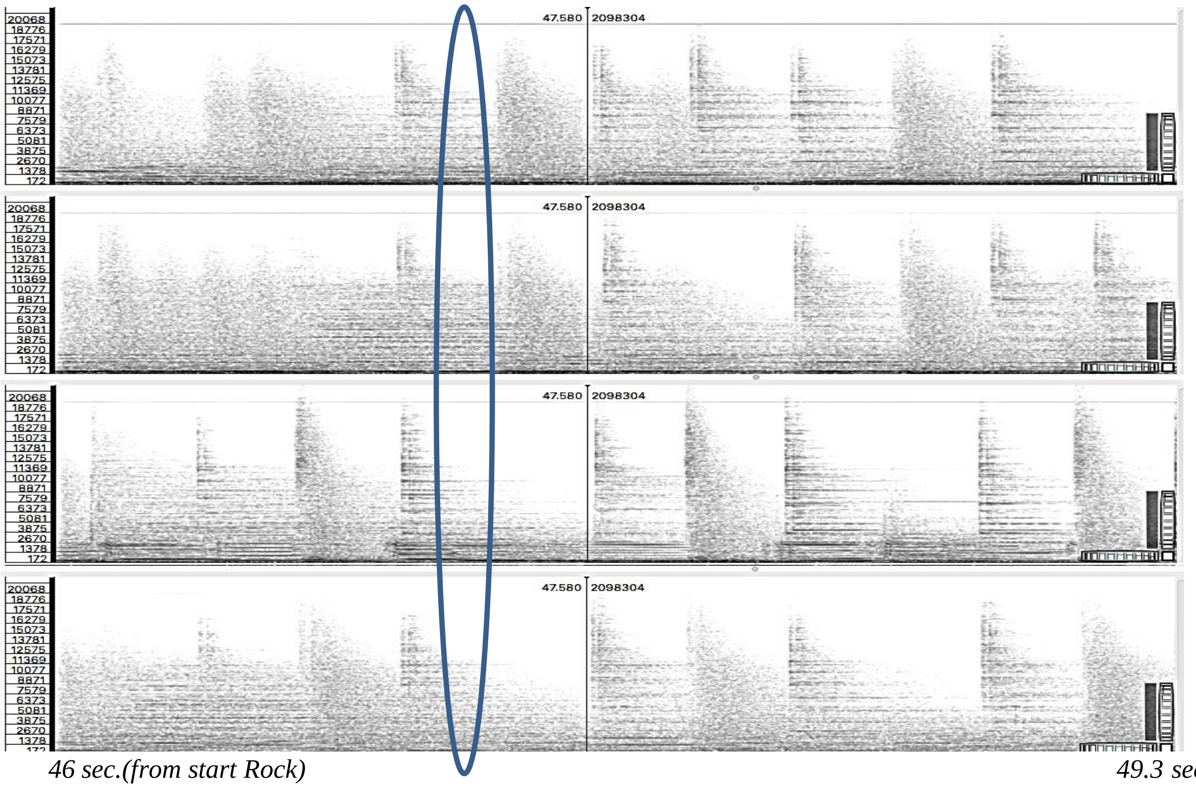
NOTELENGHTS ROCK

Spectrogram whole Rock part: (Chamber/Amplified/Zetlitz/Concert)



0 sec. (start Rock) *1min. 09 sec.*

ROCK Zoom in:



46 sec.(from start Rock) *49.3 sec.*

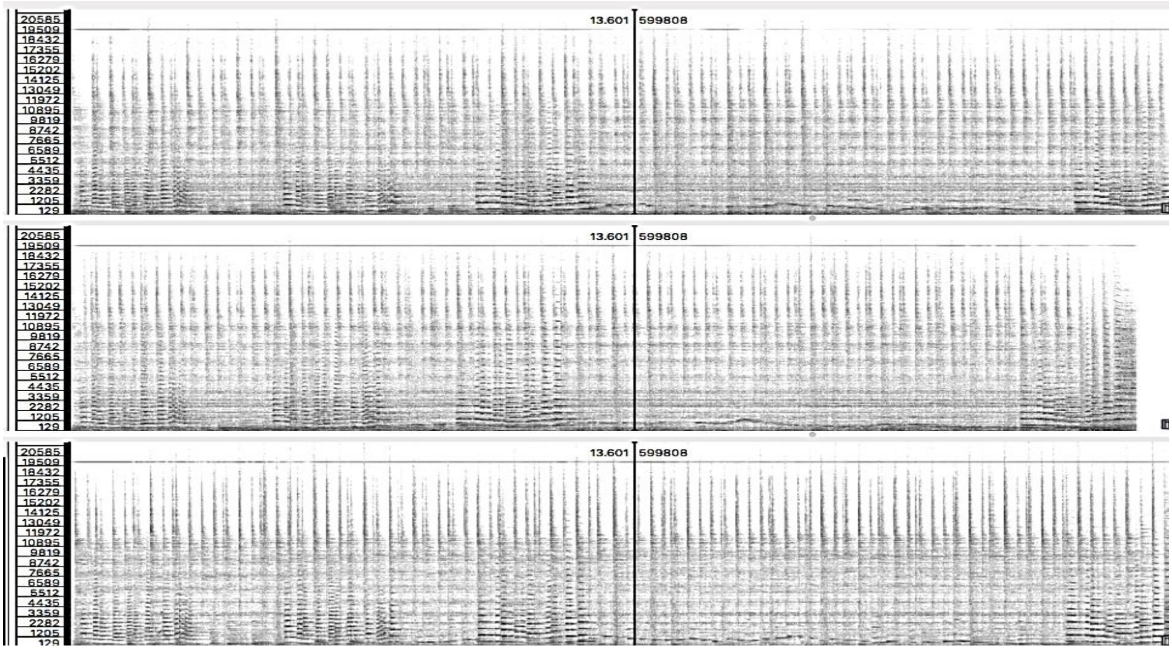
The shorter decays in *"5.Zetlitz"* is clearly shown. PS! The reason why the decay seems shorter also for *"6.ConcertBig"* might be because of somewhat lower SPL at that time(?)

NOTELENGHTS JAZZ

Chorus1(trpt.)(12 bars)+chorus 2(piano ad lib 8 bars and trumpet lead for the last 2bars).

Chamber, ***Zetlitz***, ***Concert***

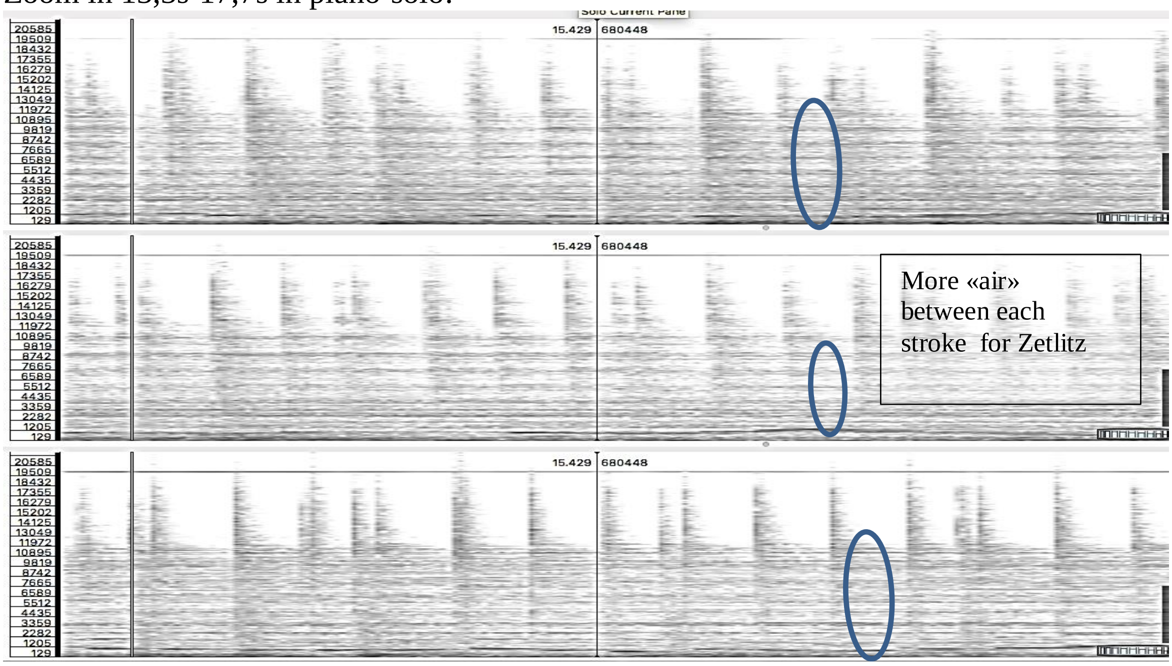
(PS! *"4.Amplified"* omitted because trumpet did not play his 2 bars at the end).



0 sec.(start Jazz) *22 sec.*

Zetlitz was played in a faster tempo!!

Zoom in 13,3s-17,7s in piano-solo:



13.3 sec.(from start Jazz) *17.7 sec.*

These figures show that many decays «hide»/»mask» the new attacks in piano for all the settings in Valen, but much less in Zetlitz.

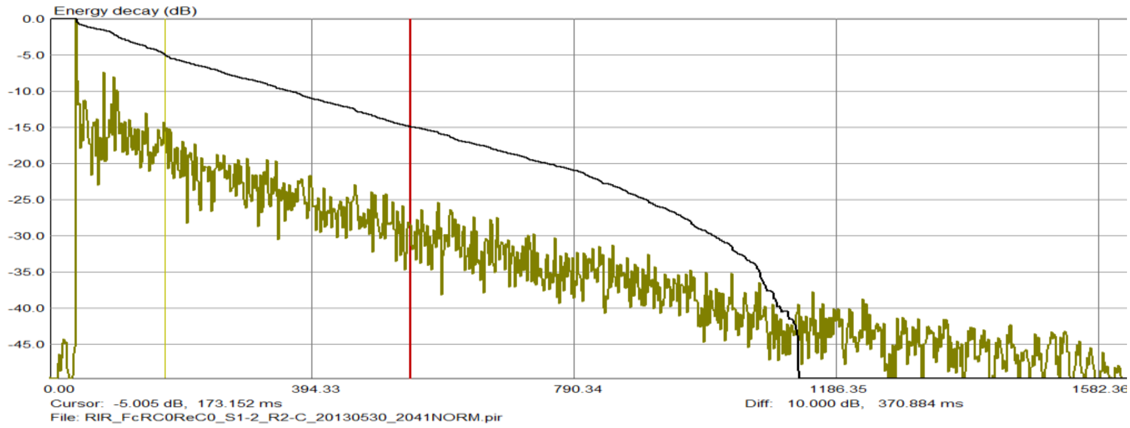
APPENDIX 5) THE INFLUENCE OF REVERB ON TIMBRE AND ATTACK/DECAY.

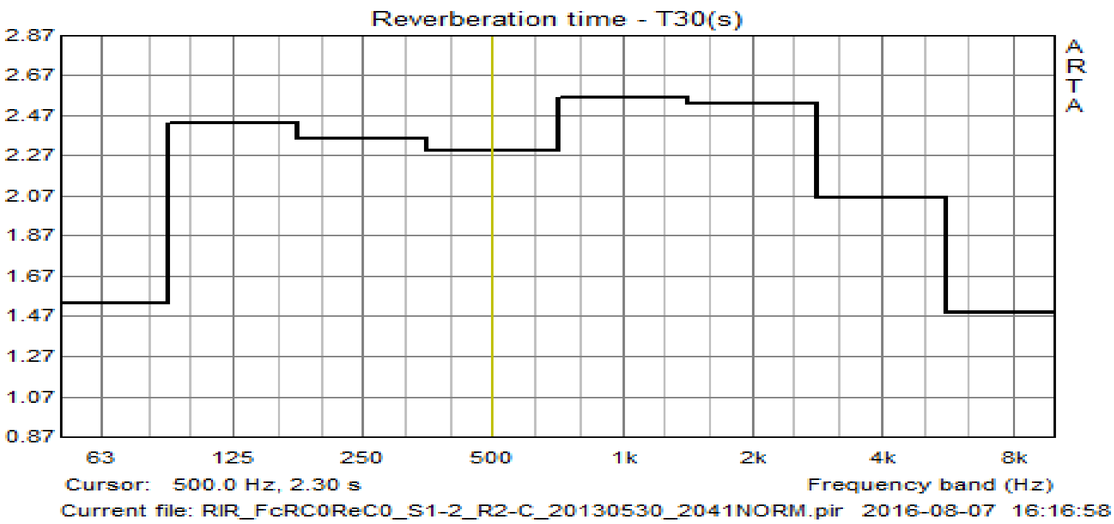
App.5.1) GUITAR, EL-REVERB AND CONCOLUTION

ADDING ELECTRONIC REVERB AND CONVOLVING A CLEAN GUITAR LICK WITH THE MEASURED IMP.RESP. OF THE HALL.

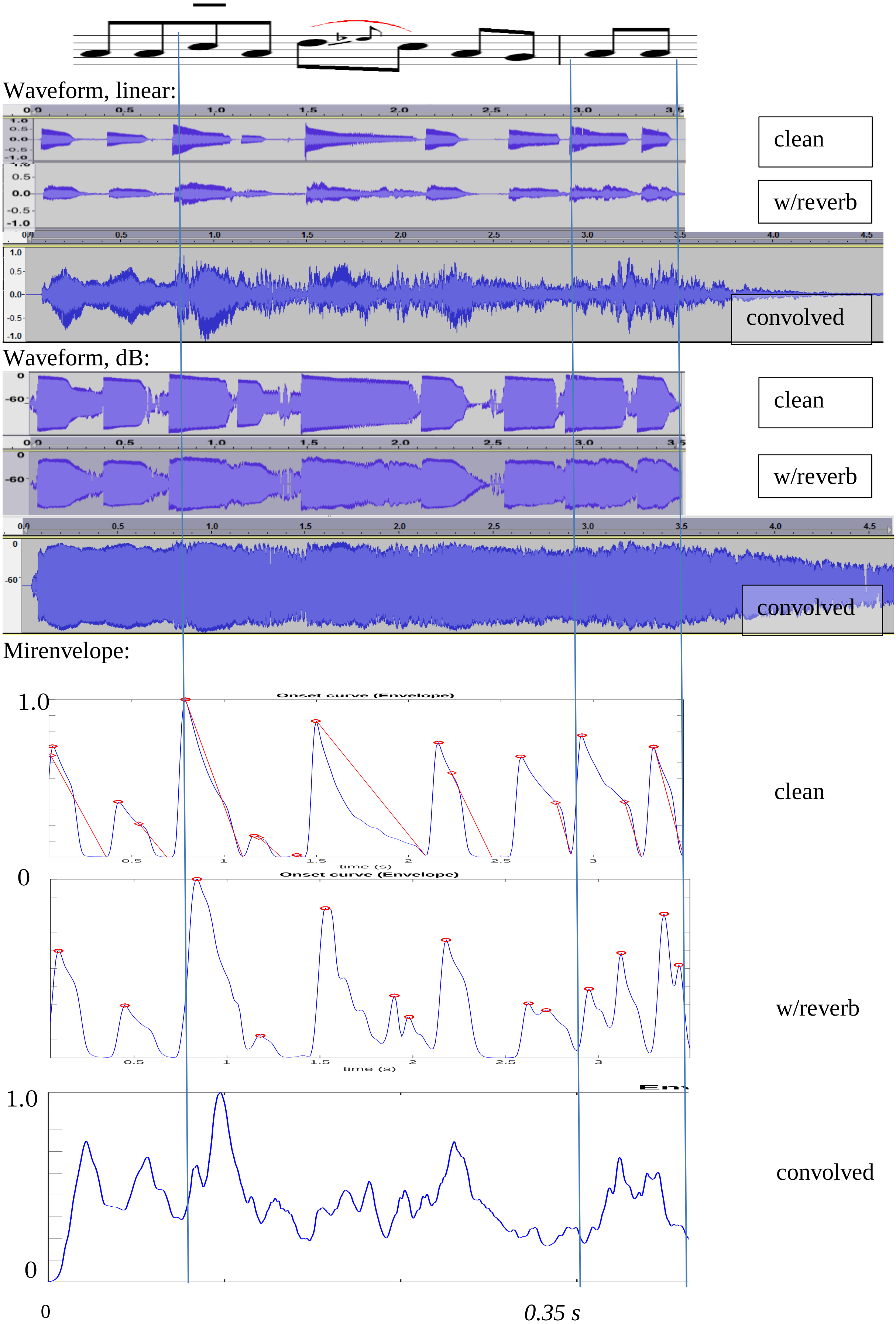
A test of adding a very moderate reverb to a short guitar lick shows some aspects on how reverb influence attack/decay and timbre. A short lick was recorded "dry" (Gibson ES 175D), and very little amount of a simple electronic reverb was added (in Audacity).

The "clean" guitar lick was also convolved (in Praat) with an Impulse Response from the acoustic measurements from Kahle Acoustics (Brian Katz et al, *file: RIR_FcRC0ReC0_S1-2_R2-C_20130530_2041*). The following figures show the Impulse Response and the Reverberation time, T30, for this measurement:



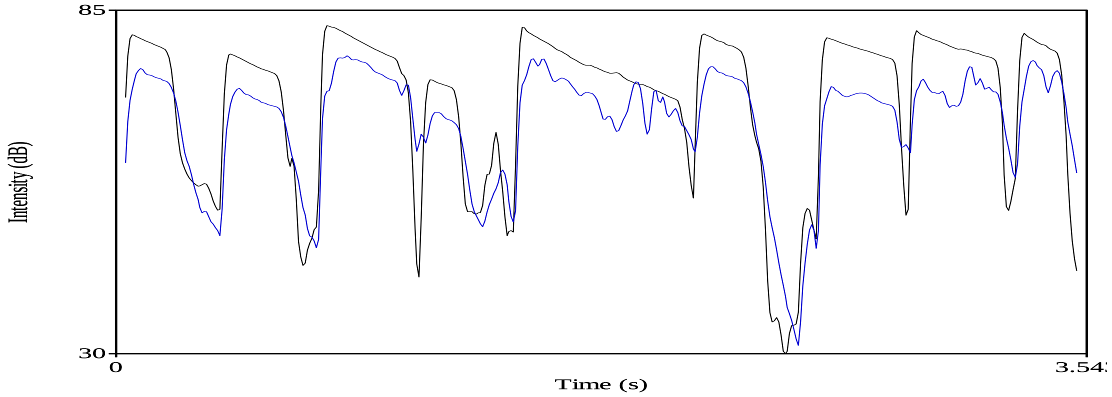


STATSBYGG



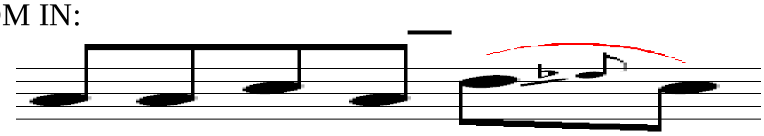
3.5 sec

PRAAT: (Black=Clean, Blue=With Reverb)

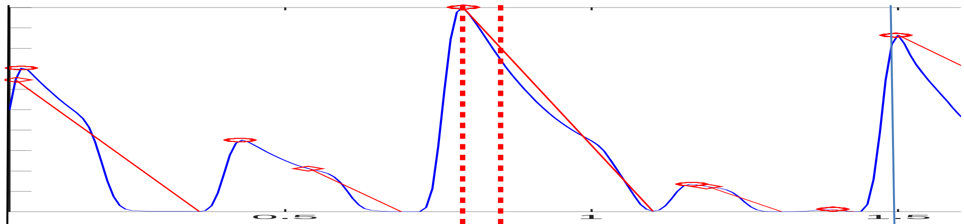


We see that even if the files are normalized, The levels for “WithReverb” are all lower than for “Clean”. We see that both the attacks and the decays are longer with reverberation.

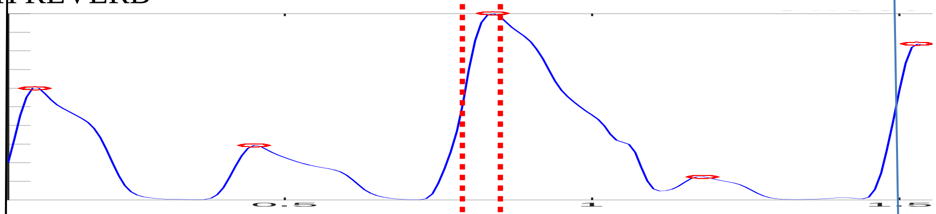
ZOOM IN:



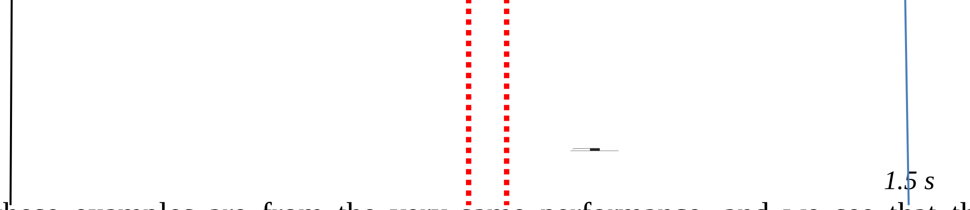
CLEAN



WITH REVERB



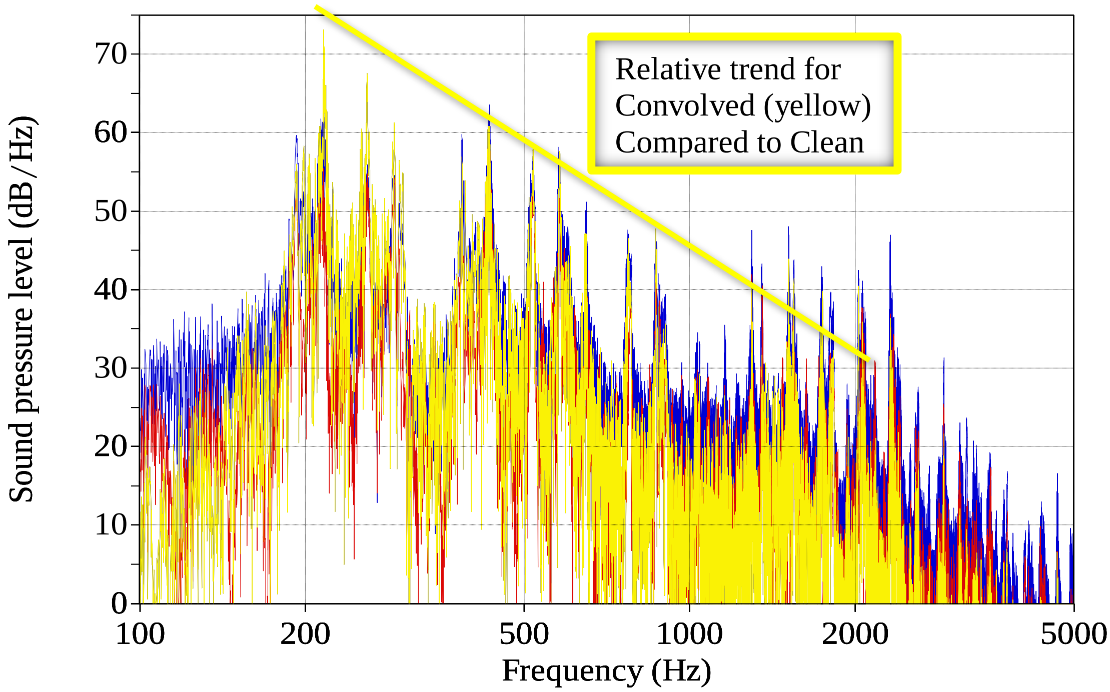
CONVOLVED



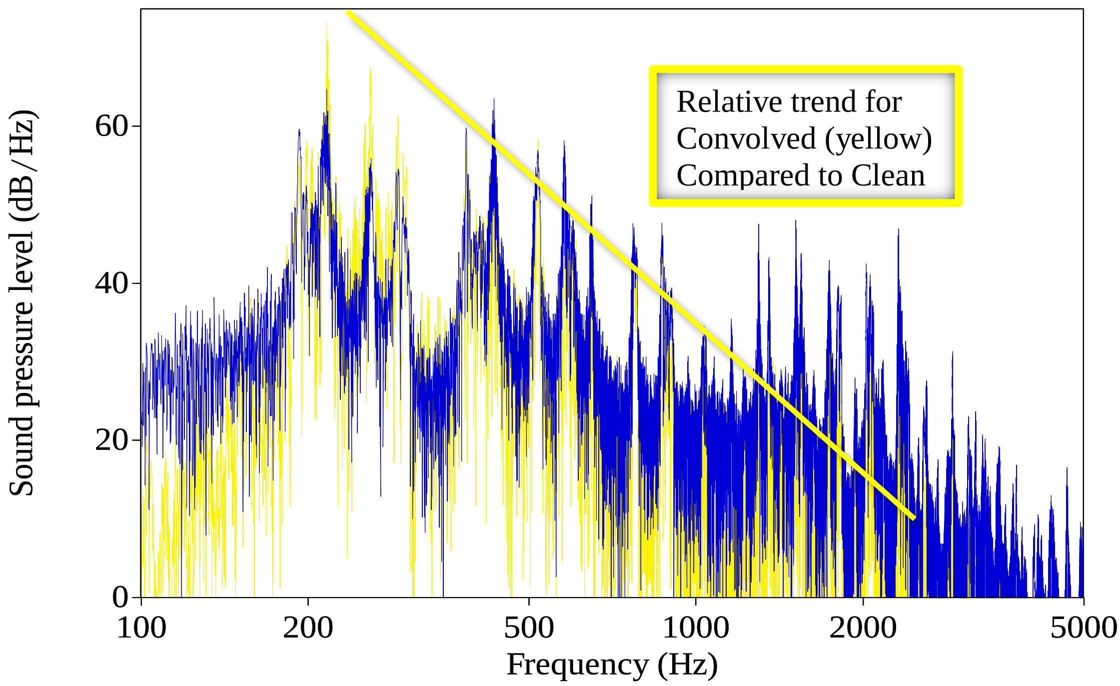
All these examples are from the very same performance, and we see that the reverberant setting makes the release times (decay) longer, and, perhaps even more important: also that the attack time is longer (more “smooth”). This is of course also seen directly from the waveforms above. The curve for the convolution file is not directly comparable, due to the automatic settings of the axis in mirenvelope, but we see that both the attacks and decays are “smoothed” giving a much more unclear “attack-timbre”, and that the decays never reach zero, meaning that **the tones easily “mask” the next attack(s).**

PS! We might use the term “attack-timbre”/”klangfarbe”, because shorter attacks will be perceived as having “more high frequencies”.

SPECTER (Blue=Clean, Red=With Reverb, Yellow=Convolved w/Imp.Resp)
(All files normalized) (Measured for the entire music).



We see that the convolution with the measured Impulse Response reduces the "higher" frequencies (above some 400 Hz), but increases the levels for the fundamental of the A minor melody (A=220 Hz, since the guitar now is tuned to 440). To show this somewhat clearer, the following figure contain just the Clean (Blue) and the Convolved (Yellow).



CENTRE OF GRAVITY (**Spectral Centroid**):

Clean:	452 Hz
With electronic Reverb:	432 Hz
Convolved w/measured ImpResp.:	291 Hz

The Spectral Centroid is somewhat reduced by adding reverb, but not very clearly (Of course this depends also on the spectre of the added reverb itself, but for a concert hall, a reduction for high frequencies is common).

Spectral Skewness:

(Measure for how much the shape of the spectrum below the centre of gravity is different from the shape above the mean frequency) (For white noise, the skewness is zero).

Clean:	3.5
With Reverb:	4.2
Convolved:	5.5

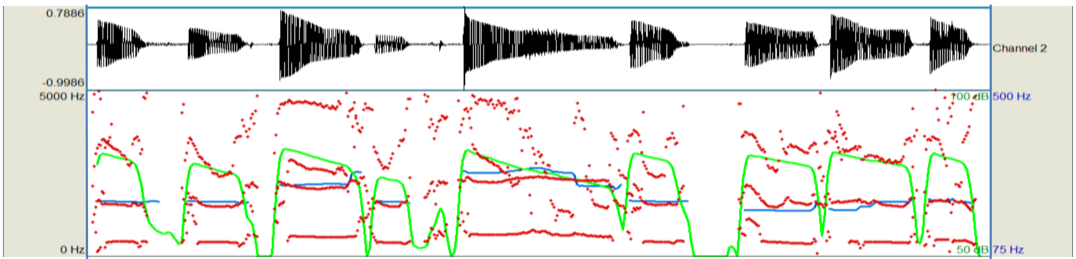
Kurtosis:

(Measure for how much the shape of the spectrum around the centre of gravity is different from a Gaussian shape.

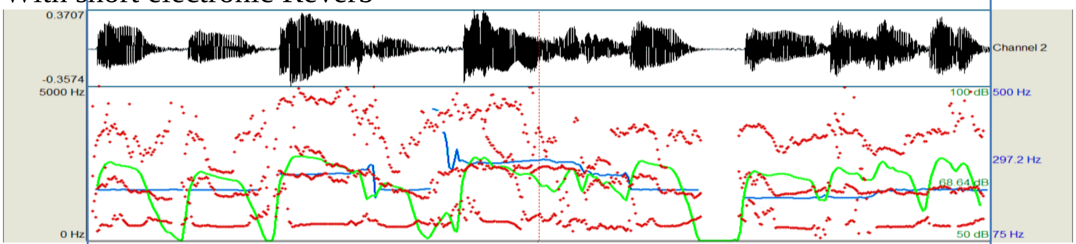
Clean:	20.7
With Reverb:	31.9
Convolved:	50.6

PRAAT overall views (Formants, Intensity and Pitch)

Clean:

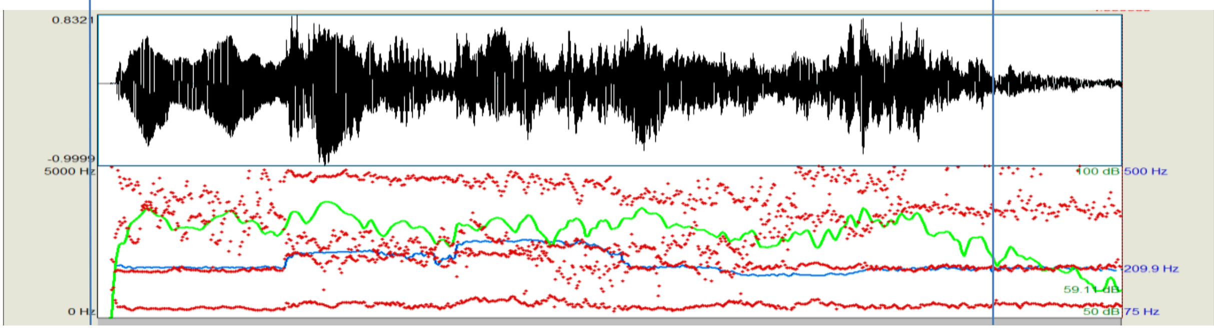


With short electronic Reverb



0 sec. *3.5 sec*

Convolved with measured Imp.Resp.:

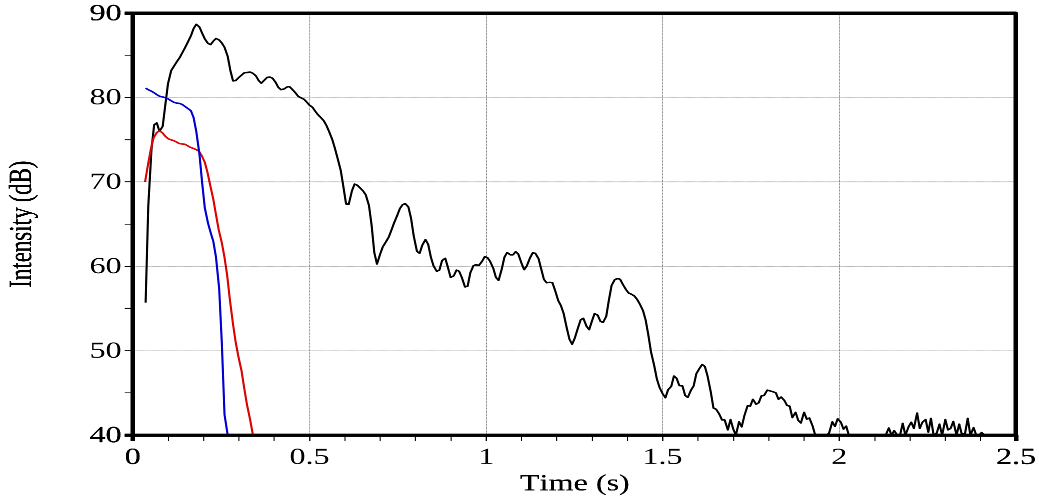


0 sec. *3.5 sec* *4.3 sec*

We see that the Praat algorithm for Pitch "has a harder job" for the reverberant version. Also the formants are more unclear after adding reverb, For the Convolved file, the changes over time of the formants are almost lost.

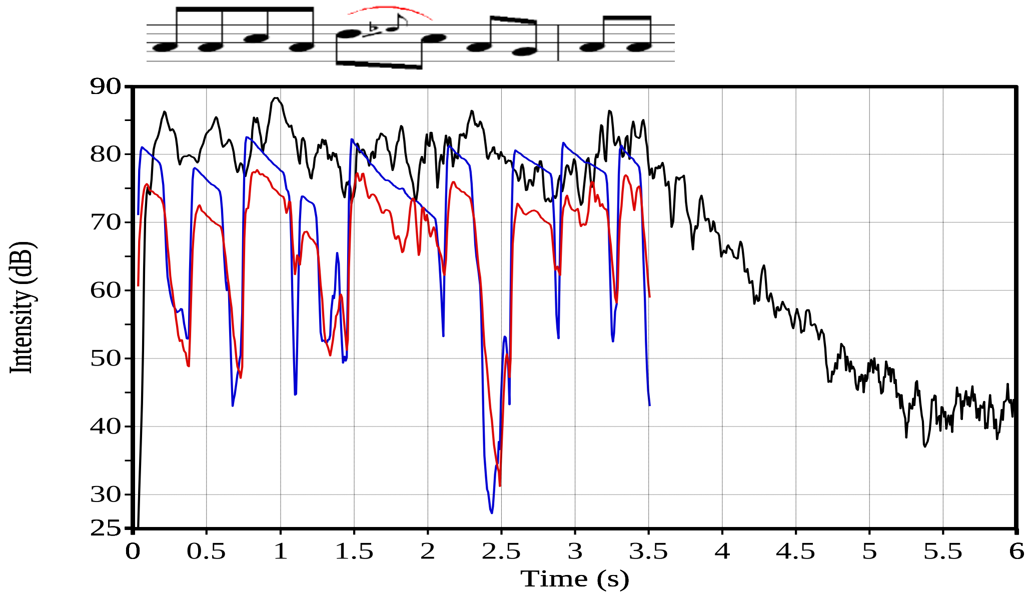
"REVERBERATION TIME" /DECAY TIME of Guitar Note with/without reverb.
Of course the guitar recording is not ideal for calculating reverberation time, and in any case, it should be called "Decay Time" or something similar. The following analyses of a single tone A=220 Hz shows that the added reverberation is moderate, but the convolved file shows a really long decay.

Red= With Reverb, *Blue= Clean, Black= Convolved*



The following figure shows the Intensity [dB] over time, and we clearly see that the F.Valen hall in a typical reverberant setting almost "removes" each attack. The three curves are all from the very same "performance" of the guitar lick:

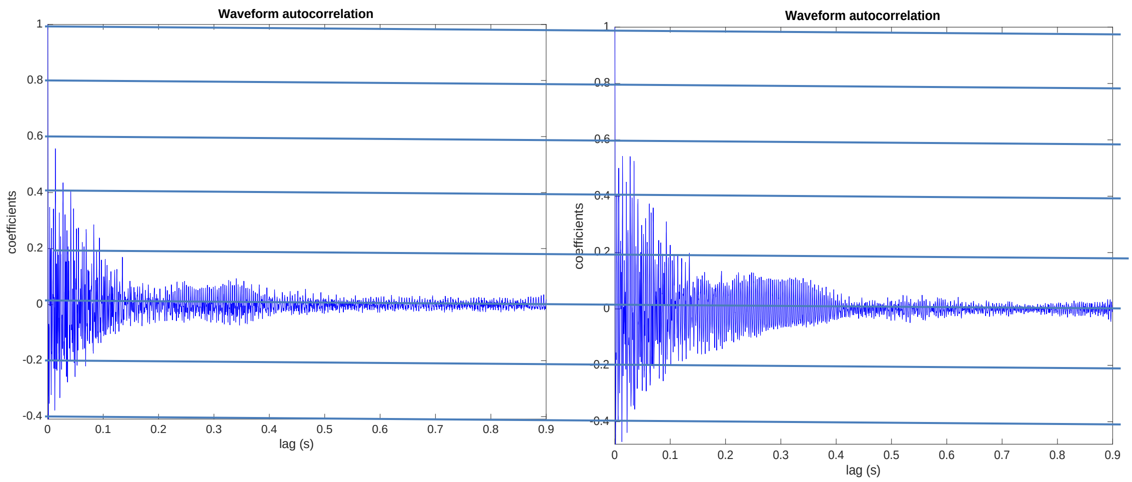
Blue = *Clean,*
Red = *with added short, simple reverb (Audacity),*
Black = *Convolved with measured Imp.Resp.*



CONCLUSION, THE INFLUENCE OF REVERB ON ATTACK/DECAY:
Even small amount of (added electronic) reverb "smoothes" the sound by prolonging both the attack-time and decay(release) time, which (often) gives a slight reduction of high frequencies. The long reverberation of a typical setting in F. Valen gives that both the attacks and the decays more or less overlap, giving the "blurring" sound clearly perceived both in the hall and listening to the recordings of short, transient tones like the (jazz) guitar (or piano).

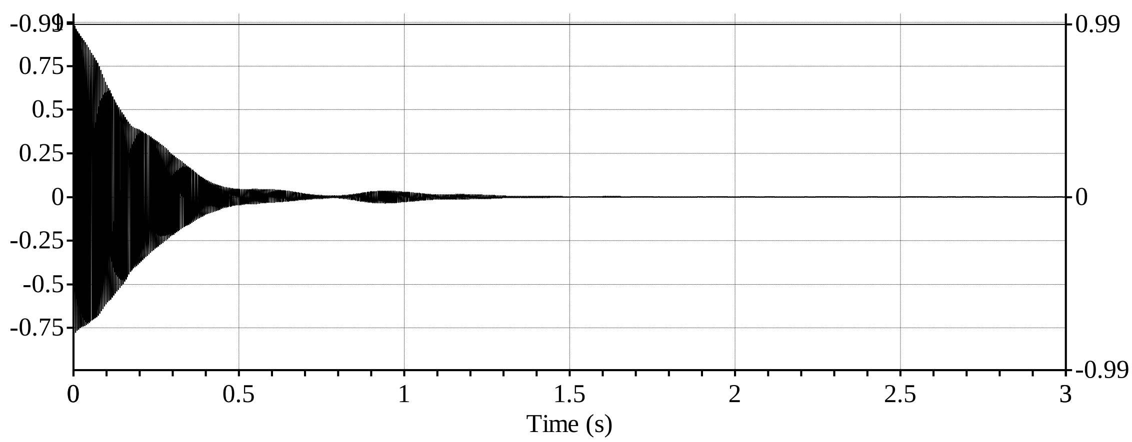
AUTOCORRELATION GUITAR LICK

Clean *w/Reverb*



For the guitar lick we (perhaps) see that the Autocorrelation increases somewhat due to the added (electronic) reverb. This might be somewhat in contrast to the findings of Autocorrelation when comparing *"5.Zetlitz"* and *"6.ConcertBig"* above. This might be due to the algorithm used for the simple Audacity reverb. In any case:

The autocorrelation of a guitar tone (A=221 Hz), convolved with the measured Impulse Response is given in the following figure:

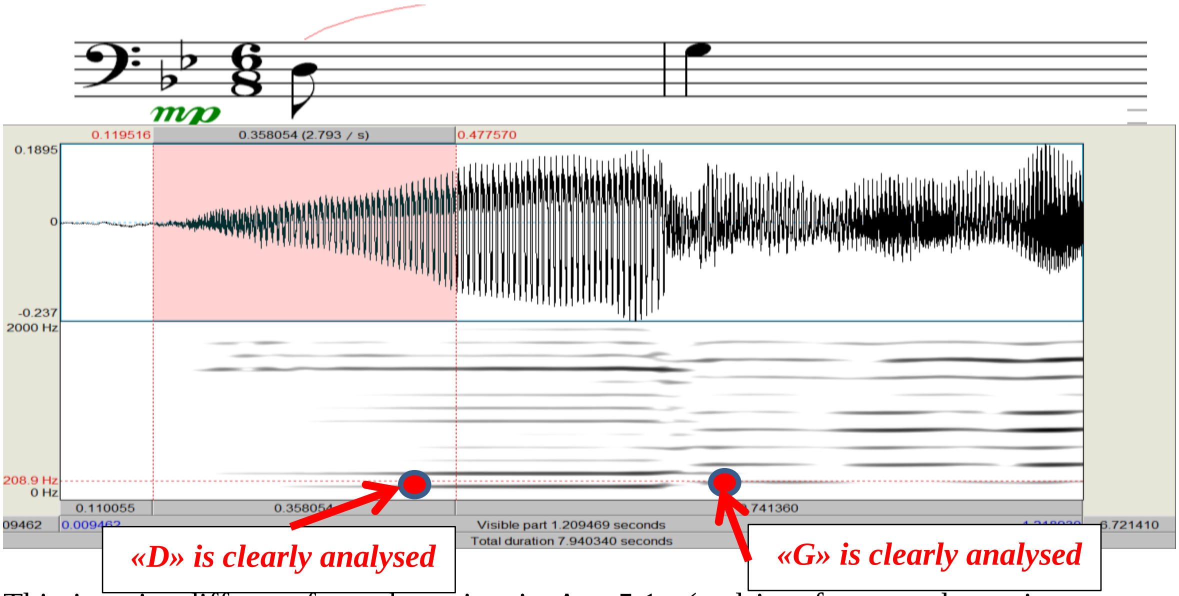


Unfortunately this test performance did not provide enough material for testing (auto-)correlation issues of reverberation in a broader sense. Correlation/Coherence MIGHT be interesting in the search of a (mir-) parameter that describes the perceived change in "timbre" when moving to a hall with more reverberation.

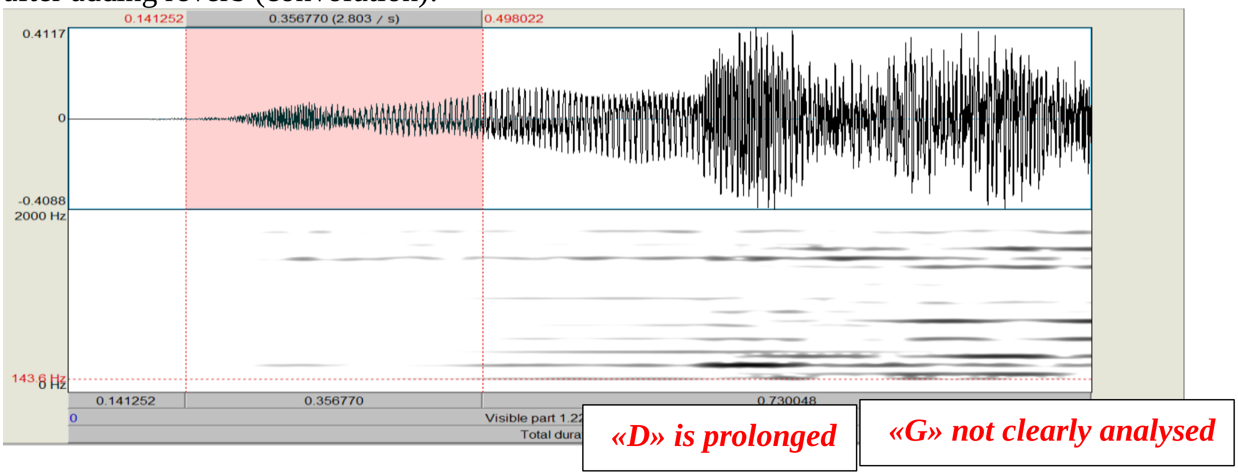
App.5.1) CELLO, CONVOLUTION

The start of an anechoic recording of a cello playing the beginning of the melody of Gabriel Faures *"Sicilienne"*, opus 78 (from the Odeon library) was convolved with the same Impulse Response from Stavanger/F.Valen as for the guitar in App.5.1.

The score indicates the dotted quarter note to be MM=50, meaning its duration should be app. 0.83 s, or each bar app. 1.66 s. The following analysis of the first two notes ("D" and "G") shows that the cello takes a long time (indicated in the graph as almost 0.35 s) to grow to a "full tone".

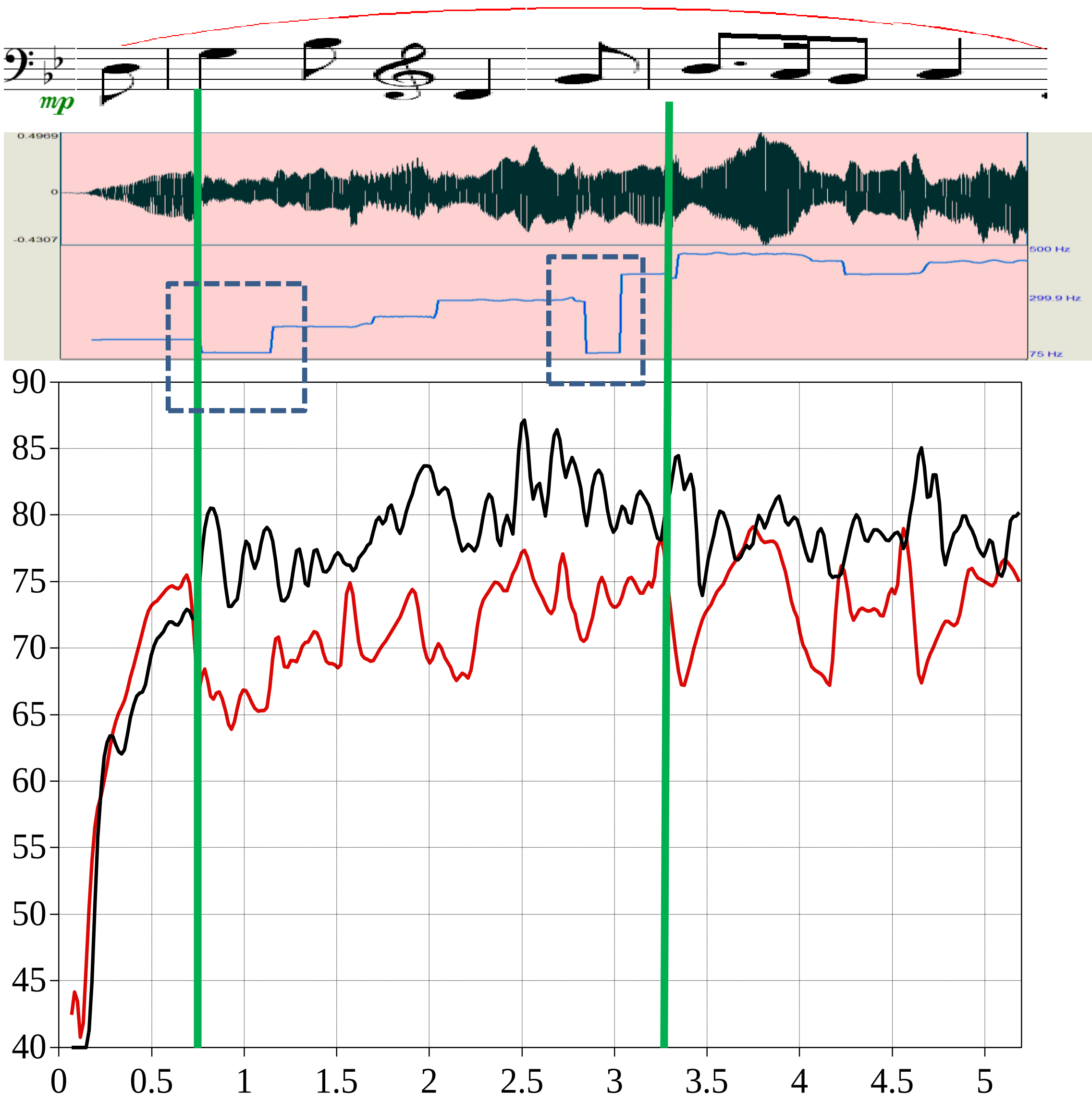


This is quite different from the guitar in App.5.1., (and is, of course the main reason why strings need more reverberation than a jazz guitar). The following shows the same analysis after adding reverb (convolution):



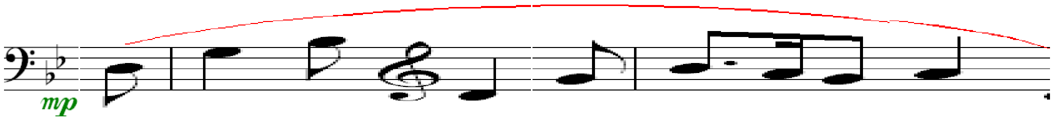
We see that the (too) long reverberation reduces the "attacktime" so the full tone is not reached before later, and the "D" is prolonged to after the "G" is played, giving the "chunk" of energy around the bar line (tone "G").

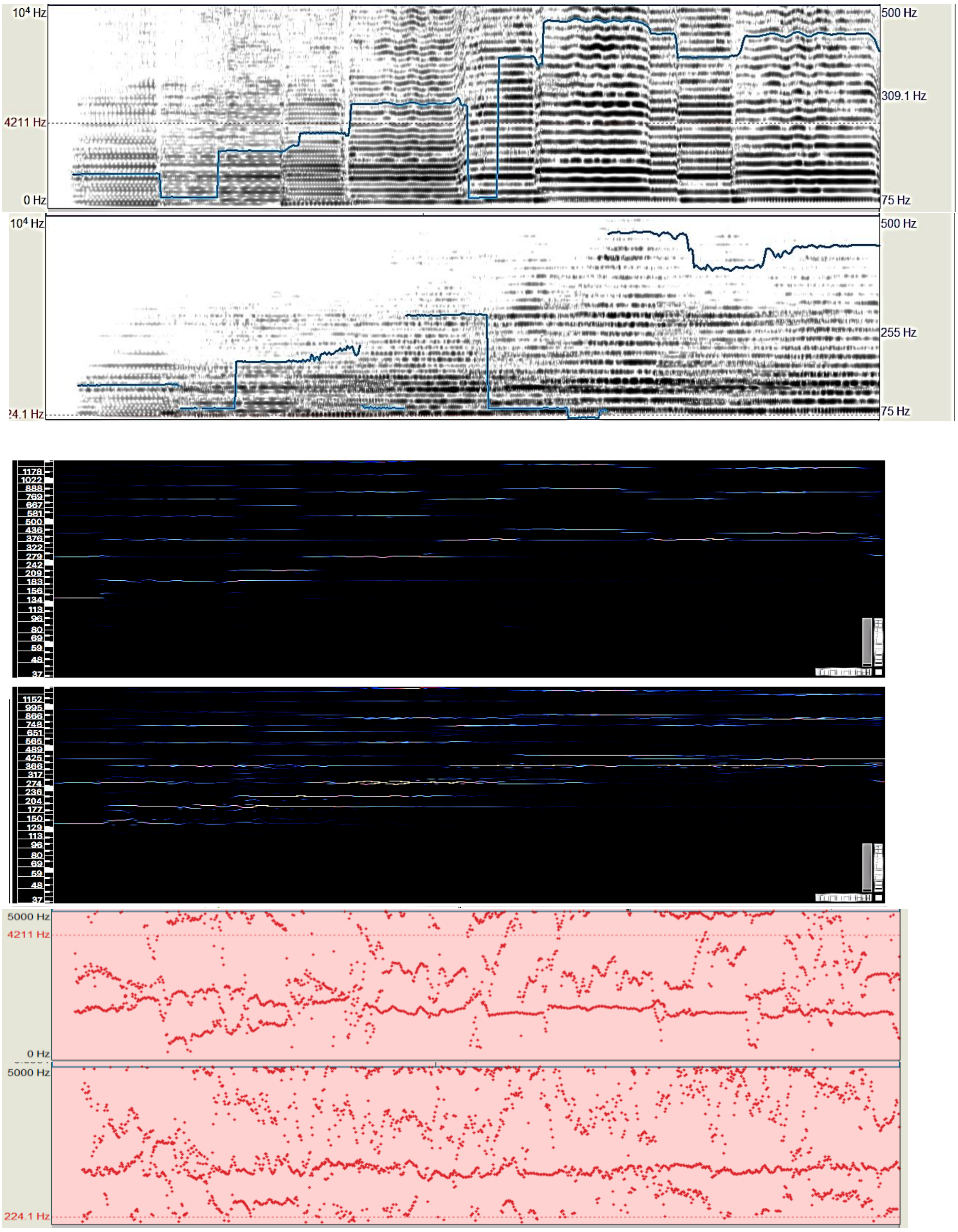
The score and several analyses for a somewhat longer part (the first 5.2 s of the recording) are shown in the following graphs. First, the intensity (dB). Red=Anechoic, Black=Convolved. (The picture in the middle is the waveform and the Praat pitch analysis of the anechoic recording,.PS! It is assumed that the Pitch analysis takes some time, and this time seems to be somewhat depending on how "clear pitch" the sound material provides. While "waiting for a reasonable analysis", Praat shows periods of "zero pitch". Listening proves that the "g" in the beginning of bar 2 is correctly positioned with the straight line all graphs, and that the pitch detection is slow. (Even the excellent Praat program takes about 0.4 s to analyse this pitch in this legato performance).



We see that adding the reverb (convolution) reduces the impact of the "space" between the "pick-up" before bar 1 (at time app. 0.7 s), and that the peaks of the anechoic "attacks" are "smoothed" or even removed to be hidden/masked by the reverberant energy. (Example: beginning of bar 2, the Bb-note at app. 3.2 s).

In the following analysis, each upper graph shows the anechoic version, and the lower the convolved.





We see that the Praat algorithm has more problems detecting Pitch for the reverberant (convolved) version. We also see from the spectrograms (*upper*: Praat, *lower:* Sonic Visualiser) that the note lengths in the reverberant setting is much more overlapping. The formant analysis at the bottom shows that the small, short deviations for the anechoic recording are “smoothed” by the reverb (convolution).

The Impulse Response from F. Valen used in this analysis is clearly “a bit too reverberant” even for string quartet, but shows the aspects on why strings need more reverberation than drums, jazz guitar/piano/rock.