



Report

Live concert sound quality **Measurements and assessments of eight concert venues**

Client: Danish Sound Technology Network

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Title

Live concert sound quality - Measurements and assessments of eight concert venues

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Client ref.**Summary**

The purpose of the project was to expand the knowledge on which parameters and attributes are important for the perceived sound quality by physical, perceptual and affective measurements at live concert events.

This report summarises data and findings from 3 scenes the Roskilde Festival and five indoor concert venues. Physical measurements of various characteristics for the sound system and (room) acoustics have been made at all venues. Audience response and perceptual assessments of live and recorded concerts have been made in various combinations.

Between the venues there were essential differences in the acoustic characteristics and the sound pressure levels during the concerts but these differences were below the just noticeable differences when the assessments were made at the live concerts with large time intervals. This might also be seen as a tolerance of variations of a magnitude similar to the differences in the physical measurements found for the venues in this project.

A comparison between the live assessment and assessments on recordings made during the concerts showed that the only significant differences in assessments were on the overall Sound quality and the Clarity which were higher in the live situation.

The results of comparisons of binaural recordings of concerts showed significant differences on most of the attributes for most of the four indoor venues. Furthermore a high correlation between the perceptual attributes Sound quality, Clarity and Treble was found.

Based on the findings from the comparisons of the recordings of the indoor venues some relations between the physical and perceptual domain could be found. The most prominent relation was found between the perceived Sound Quality and the EDT of the bass.

DELTA, 30 August 2013



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1. Background

At live-events with PA systems¹, there are no standards for the good sound experience. A single standard Nordtest NT ACOU 108, reference [1], provides different measurement methods for PA systems, but does not contain any minimum specifications. The influence of the acoustical properties of the concert area, and the following requirements for the speaker systems are only partly taken into account, by measurements of the Speech Transmission Index (STI). This means that the perceived quality of a live concert varies, and there is no basis for a common set of specifications to be used by manufacturers, venues etc.

Additionally, it is not clear which electro- and room acoustic parameters have the greatest impact on the perceived sound quality, and what the optimal values and allowable tolerances are on these parameters.

This project seeks to establish knowledge as the background for sound quality specifications, by physical, perceptual and affective measurements at live events.

During this project, data has been collected at the Roskilde Festival 2011 and 2012 and combined with previous results, achieved by subjective and objective measurements on five indoor concert venues in 2011 and 2012.

2. Purpose

The purpose of the project is to expand the knowledge on which parameters and attributes are important for the perceived sound quality, by:

- Defining and evaluating characteristics (attributes) for the perceived sound quality of PA-systems at live-events.
- Determining how the audience preferences (with regard to perceived overall sound quality – good / bad) depend on these characteristics.
- Figuring out how these characteristics are best represented by physical measurements of the sound quality, to thereby give a background for sound quality specifications.

¹ A PA system is an electronic sound amplification and distribution system with a microphone, amplifier and loudspeakers originally used for Public Address purposes. Now a days the term is used in general for sound reinforcement systems and the term is widely used also for concert sound systems.

3. Definitions and general methods

3.1 Main principle for measurements

The project baseline is the wish to establish a connection between the physical measurements (Physical domain, measuring point M1 – diverse acoustic metrics), the perceived sound (perceptual domain, measuring point M2 – perceptual attributes) and the experienced sound (affective domain, measuring point M3 – audience preferences) as illustrated in the filter model below.

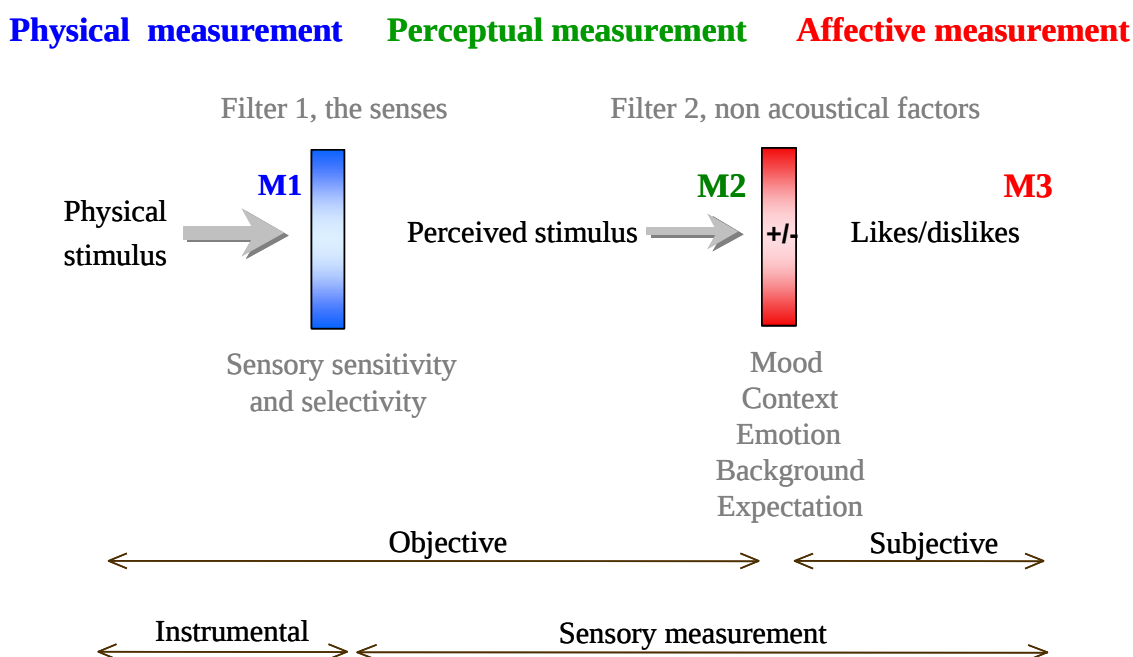


Figure 1

The filter model illustrates the relations between physical (instrumental) measurements and the sensory (perceptual and affective) measurements.

The physical metrics can be i.e.: Room acoustic metrics (EDT, T_{10} , T_{20} , T_{30} , T_s , C_{80} , D_{50}) metrics for sound pressure levels (e.g. L_{Aeq} , L_{AmaxF} , L_{Cpeak}), speech intelligibility, frequency spectrums etc. For definition of these see clause 6.1.

The perceptual attributes (assessed by experts) can be i.e.: perceived sound quality, sound level, clarity, bass-precision, bass-level, treble-level, distortion, hum and noise, stability (time wise variations due to weather variations for outdoor venues).

The affective attributes (evaluated by the audience) could be i.e.: “I like” the venue, the band, perceived sound quality, sound level.

Through statistical modelling and analysis, an attempt is made to establish a connection between the perceived sound quality, the sensory attributes and the electro- and room acoustic parameters. Hereby it is sought to determine which of these have the greater influence on the experienced sound quality for guidance to the optimal values and allowable tolerances for these parameters.

3.2 The venue

The complete PA system can be considered from a point of view where there is an A-chain and a B-chain together resulting in the sound that the audience hear, see Figure 2.

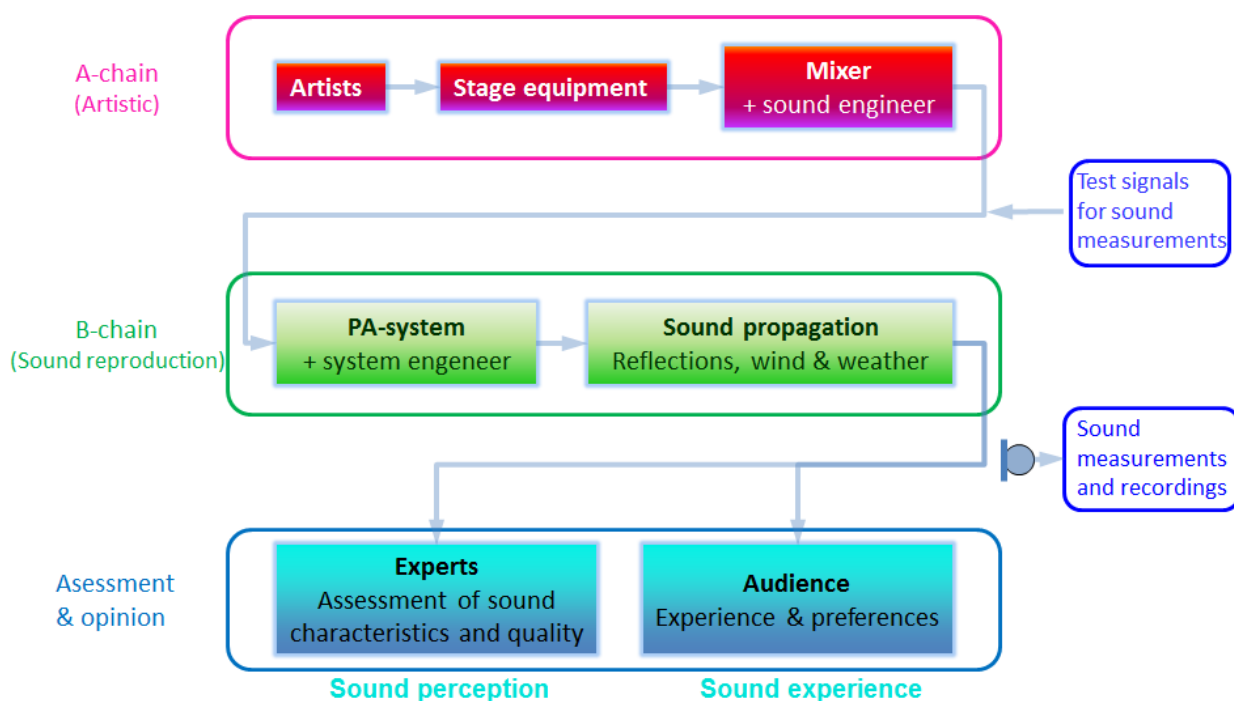


Figure 2
Sound reproduction chain for live music situations including measuring points for physical and sensory measurements.

The A-chain is the artistic chain, meaning the performers, the stage equipment and the mixing and effects made by a sound engineer with relations to the performer.

The B-chain consists of the PA-system, meaning the system signal processing, amplifiers and loudspeakers (whose main purpose is to amplify and reproduce the signal from the A-chain) and the venue acoustics for outdoor events including the influence of wind and weather on the sound propagation. The PA-systems are typically temporary installations for

outdoor venues and a permanent installation for indoor venues and they are adjusted to a specific frequency response and maybe a limited maximum sound pressure level, etc.

With the many signal processing options available to the A-chain, the sound characteristics and quality of a certain B-chain might be perceived very differently depending on the settings of the A-chain.

4. Venue measurements

The measurements were performed at one outdoor and two tent stages at Roskilde Festival with temporary PA installations and at five indoor venues with permanent PA installations.

4.1 Roskilde Festival

Measurements were carried out on 3 of the 7 stages at the Roskilde Festival, during two concerts on each of these stages. The Orange, Pavillion, and Cosmopol stages were chosen.

4.1.1 Orange stage - Roskilde



Figure 3
Roskilde Festivals main stage, 2011. Open air type, with delay systems for the audience at the back. Up to 60.000 people. L-Acoustics K1 sound system. The measurements were performed in 2011.

4.1.2 Cosmopol stage - Roskilde



Figure 4
Cosmopol tent. Primarily features electronic, R&B and hip hop music. Max 5000 persons. Equipped with a D&B sound system, including subwoofers that extend down to 27Hz. The measurements were performed 2012.

4.1.3 Pavillion stage - Roskilde



Figure 5

Pavillion tent, All-round stage featuring everything from intimate acoustic concerts with few instruments, to heavy metal. Max 2000 persons. This stage is equipped with a Meyer Sound sound-system. The measurements were performed 2012.

4.2 Indoor venues

4.2.1 Gimle – Roskilde



Figure 6
Gimle, “Tanken”-stage. Max 690 persons. D&B Sound system, Digidesign digital mixer.

4.2.2 Kulturstationen . Vanløse



Figure 7
Kulturstationen café stage. Max 150 persons. L-acoustics top speakers, custom-made sub-woofer. Yamaha LS9-32 digital mixer.

4.2.3 Forbrændingen - Albertslund



Figure 8
Forbrændingen “salen”. Max 400 persons. L-acoustics sound system, Midas H1000 analog mixer.

4.2.4 Store Vega - Copenhagen



Figure 9
Vega large stage. Max 1550 persons. D&B sound system, Midas H2000 analog mixer.

4.2.5 Mantziusgården – Birkerød



Figure 10
Mantziusgården, “salen”. Max 700 persons. Meyer Sound sound system.

5. Measurements

5.1 Measurement overview

Sensory evaluations were performed on relevant attributes during the concerts, along with measurements of sound pressure levels and spectra. Concerts where permission was granted by the band were recorded as a binaural recording on a hard disk recorder from a Brüel & Kjær Head and Torso Simulator (HATS). These recordings are available for lab tests.

The subjective sound quality ratings from the audience were registered by pen and paper at the indoor venues, and by participative smart-phone software on Roskilde Festival 2012 (no audience data from Roskilde Festival 2011).

Table 1 gives an overview of the activities during the PA sound quality project.

Location	Venue	Orange scene	Gimle	Kulturstationen	Forbrændingen	Store Vega	Manziusgården	Cosmopol	Pavilion
Live venue	Band	Ravinettes Kaizers	Simpson	Simpson	Simpson	Simpson	Tim C	Analogik Les Freres Smith	Django Django Of the wand and the moon
	Acoustic measurements	●	●	●	●	●		●	●
	Binaural recordings		●	●	●	●		●	●
	Audience response		●	●	●	●	●		
	Perceptual measurements	●				●	●	●	●
Listening room	Perceptual comparison		●	●	●	●			

Table 1

Overview of activities during the PA sound quality project. The colors indicate the band

From the measurements, we can:

- Assess the sound on different stages at the Roskilde Festival (Orange, Cosmopol and Pavilion) with two different bands on each stage
- Compare binaural recordings of different indoor venues with the same band and sound engineer (concerts with Simpson).

- Compare audience response and “live”-perceptual measurements (Store Vega and Manziusgården).
- Compare sensory measurements with acoustic measurements of PA systems and concert sound (concerts with Simpson).
- Compare “live” perceptual measurements with comparative perceptual measurements in a listening room (Store Vega).

By statistical mapping the relations between perceptual measurements (sound quality profiles) with audience preferences and physical measurements can be found. This mapping attempts to:

- Establish an overview which explains the audience preferences based on the perceived sound quality profiles. (which characteristics are good, which are bad)
- Establish a model which can relate the perceived sound quality profile to the physically measureable metrics. This could be the part of the background for specification of good PA sound.

For all venues the physical measurements and the perceptual assessments were made in the same positions. Positions for audience responses were also registered but not used in the analysis.

5.2 Acoustic measurement procedures

Physical measurements of room acoustics and the PA system were performed on each venues – with the exception of Mantziusgården.

Measurements were taken in a rectangular grid of 3x3 i.e. 9 positions in the audience area. Each set of 9 measurements lasted about 10 minutes, and consisted of a series of Dirac impulses, pink noise and short (0.9s), and long (11s) logarithmic sweeps stored at a CD and played back over the PA-system.

During the measurements 3 people carried a microphone and a hard disk recorder each – making it possible to measure at 3 points at the same time. Measurement points were located and marked before the acoustic measurements, making it fast to move the microphone from one position to the next.

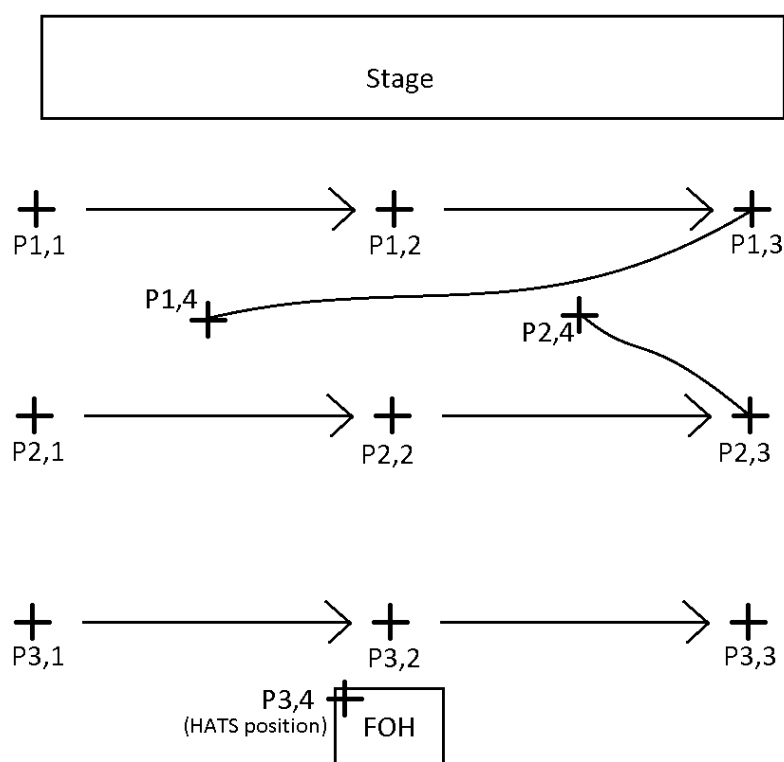


Figure 11

General layout for the acoustic measurement locations. The arrows indicate the order of the measurements. Binaural recordings of the concert were made in the HATS position near the front of house (FOH) with the mixer.

A spare set of measurement signals were included at the CD containing the measurement signals – in case one measurement point was ruined by background noise or otherwise missed. No problems were encountered, so this last (4'th) measurement point (pr. row) was placed at the locations given Figure 11 and in Appendix 12 (for Roskilde Festival 2012 only).

An additional a measuring microphone was placed at the HATS position.

The field measurements data were processed with the Brüel & Kjær Dirac measuring system and the noiseLab sound level software from DELTA.

5.3 Oticon Measurements

In corporation with the Danish hearing aid manufacturer Oticon, measurements of the sound pressure levels during the concerts among the audience were made at Roskilde Festival. Each expert assessor attending the concerts was equipped with a specially programmed Oticon hearing aid. The hearing aid acted like a sound level meter which measured the sound

pressure levels in three frequency bands (bass, midrange, treble) every 2-3 seconds during each concert. The data was processed by Oticon and is visualized as video clips showing the levels in each of the frequency bands during the concerts.

5.4 Concerts recordings

The concerts were recorded using a calibrated Brüel & Kjær HATS type 4100, placed in the front left corner of the front-of-house booth at Roskilde Festival and close to the mixer for the indoor venues. No recording were made at the Orange scene.

A sound field microphone was meant to record the concert for later possible reproduction in a surround format, but even in the least sensitive setting the preamplifier of the microphone was overloaded due to the loud bass content in the concerts.

A measuring microphone was placed close to the HATS position. After the concerts, the sound pressure levels were measured from these recordings, using DELTAs noiseLAB software.

5.4.1 Roskilde Festival

The concerts for measurements and recordings were selected in an attempt to have different styles of music, to ensure that primarily the sound-system, and not the musical genre was evaluated. They were furthermore selected to be reasonable in terms of time of day (for the sake of the expert assessors).

The selected bands for 2011 were (two concerts at Orange scene the same day):

- Raveonettes – Danish simplistic noise rock/pop. Using distorted guitars, noisy amplifiers and male/female harmonies in the vocals.
- Kaizers Orchestra – Norwegian alternative gypsy rock, using pump-organ, guitars and percussion.

The selected bands for 2012 (Cosmopol and Pavilion scenes) were:

- Analogik – Danish polcatronica. Electronic music with brass horns and a large punchy bass content. Mixed rap and singing.
- Les Freres Smith – French afrobeat band, heavily inspired by James Brown and Fela Kuti. Using many brass horns – saxophones, trombones etc. also includes guitars, bass, percussion etc. to create a funk / big-band style sound.
- Django-Django – British indie rock band, using synthesizers, bass, drums, guitars and different percussion instruments.



- Of the Wand and the Moon – Danish band with dark male vocals, female choir and varying acoustic instruments. Described as dark neo-folk / Germanic post-industrial.

5.4.2 Indoor venues

The same band with the same audio/mixing engineer was measured and recorded at 4 different venues, see Table 1.

This artist was Mikael Simpson, Danish singer/songwriter using many electronic elements (samples, beats, voice effects etc.), the sound engineer was Jacob Navne.

Another concert was evaluated on the venue Mantziusgården. This concert was performed by Danish singer/songwriter Tim Christensen and the Damn Crystals. A guitar driven pop/rock sound with some mellotron background, no digital effects. This concert was not recorded, as permission was not given by the band.

5.5 Perceptual assessments at the venues

14 expert assessors (including 3 SenseLab employees) were selected from SenseLabs normal hearing listening panel. Each of the assessors has been trained in the use of the attributes, and they are used to perform attribute listening tests at DELTAs listening facilities before.

At the locations each expert assessor was carefully instructed in the meaning of each attribute, and was instructed to make the evaluations after 30 minutes at their designated position. If the assessors chose to wear hearing protectors they were instructed to keep their hearing protectors on for at least 15 minutes, before making the evaluations. Oticon hearing protectors (ear plugs) were handed out to the assessors before the concerts in Roskilde. For the indoor venues the assessors could use their own hearing protectors.

The evaluations were done with pen on a small assessment notebook, which was handed out after the instructions. The notebook for Roskilde Festival for 2012 is shown in section 10 Appendix. Similar questionnaires were used for the other venues.

The attributes to be assessed on the 15 cm answering scales were:

- Lydkvalitet (Overall Sound Quality)
- Lydstyrke (Loudness)
- Klarhed (Clarity)
- Stabilitet (Stability due to wind) – not for indoor venues
- Bas (Bass – the relative loudness of the bass)



- Diskant (Treble – the relative loudness of the treble)
- Bas præcision (Bass precision) – not for Roskilde 2012
- Forvrængning (Distortion)
- Brum og susen (Hum and hiss)

All attributes were in Danish, since all assessors are native Danish speaking. The description for each attribute is given in the evaluation notebook in in section 10 Appendix.

5.6 Perceptual comparisons in the listening room

All concerts where permission was given were recorded using a dummy head (HATS – Head And Torso Simulator). The result of this technique is a binaural recording, which mimics the acoustic interference, which the human head creates in a sound field.

Playback of this type of recording through headphones, gives the listener an experience which is very close to the experience of actually being in the original recording situation. The spatial localization works better than on normal stereo recordings, and the problem of localization of sound sources inside the head (as with normal stereo recordings played over headphones) is not present to the same extent.

The dummy head is an approximation to the average head- ear- and body shape of many people. The fact that humans are slightly different – in this case – especially in the small structures of the pinnae, causes some spatial cues which are used for localization to be slightly inaccurate.

Binaural concert recordings were used for a listening test (perceptual comparisons) on the four indoor venues with Mikael Simpson band. The same attributes as mentioned in section 5.5 were assessed.

Due to the high sound pressure level of the concerts, the sample clips could not be presented at the actual and calibrated levels due to hearing damage risk. The sound samples in the listening test were all presented at a sound pressure level of $L_{Aeq} = 85$ dB. For a listening test of less than 2 hours duration, this is well below the maximum sound exposure limits for noise at work [3] .

The listening tests were performed in DELTA SenseLab's Listening room fulfilling the EBU 3276 and ITU-R BS.1116-1 recommendations. Sennheiser HD-650 open circum aural headphones were used for the treble and midrange reproduction and a Genelec 1093A subwoofer was used for the bass. The subwoofer was placed close to the listener and the total reproduction was equalized in 1/3-octave bands with a B&K HATS type 4100 in the listen-



ing position. The subwoofer along with a dim lighting in the listening room gave the assessors a more realistic feeling of the concert situation.

Presentation and randomization of the sound samples was handled by the Internet based SenseLabOnline software, ensuring a double blind test type. An example on the user interface is shown in Figure 12. The songs selected for the test had pre-recorded tracks as part of the performance. This meant that the musical key and pace were the same at all four venues, so these songs could be synchronized in SenseLabOnline so that the only audible change, when the listener switched (cross fade time: 40 ms) between the recordings from the different venues was the change in the sound characteristics caused by the PA systems and the venue acoustics (and minor variation due to the artistic performance).

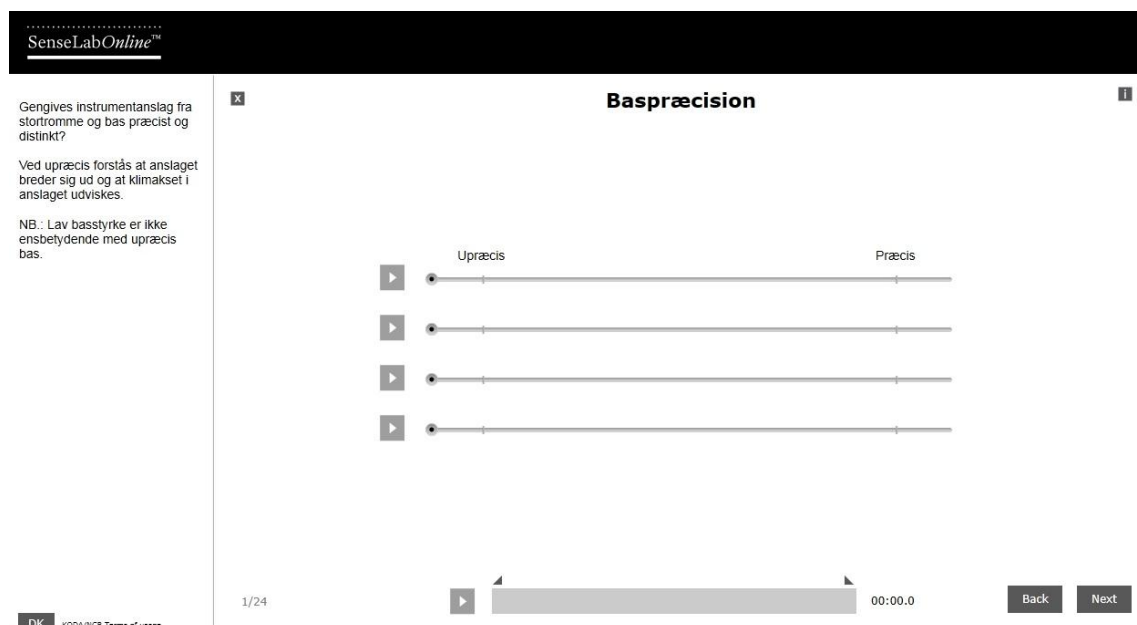


Figure 12

Example on the SenseLabOnline user interface used at the perceptual comparisons in DELTA SenseLab's listening room. By switching between the four different play buttons the listener can compare the same (synchronized) song at the four different venues.

5.7 Audience response

5.7.1 Roskilde 2012

Participative software for smartphones was meant to collect data about audience preferences.

The Audience responses was collected by the Roskilde SoundRate app, developed by DTU IMM. The App was available for download by the audience during the Festival. Details about this app are available in reference [2].

During the whole Festival 204 persons gave assessments via the App, but none of these assessments were made in the time intervals for the selected concerts so no audience responses were available for the purpose of this project.

5.7.2 Indoor venues

At the indoor venues questionnaires, see 11 Appendix, were handed out to the audience before the start of the concert and collected afterwards. The audience was asked to mark their position in the room and to evaluate:

- The service of the venue
- The Band and the music
- The Sound Quality
- The loudness of the music

The questions about the service of the venue and the liking of the band were added to see if there were bias effects from these issues to the evaluation of the Sound Quality.

44 -77 answers per venue were collected after the concerts.

6. Results

As mentioned earlier the measurements were made using the installed and adjusted PA system as sound source. The reason for this choice was to acquire measurements representative for audience perception with the given PA system locations and settings. The room acoustic results are therefore not directly comparable to results from “ordinary” room acoustic measurements which are normally made with an omnidirectional sound source.



6.1 Acoustic measurements

The acoustic measurements were performed at the 8 venues in 9-12 positions each.

From the analysis of the signals recorded on the hard disc recorders the following parameters were found:

- Frequency responses of the PA system
- Early decay time: EDT. Relates more than the other reverberation parameters to the initial part of the decaying energy and is the reverberation time measured over the first 10 dB of the decay, see Figure 13.
- Reverberation times: T_{10} , T_{20} , T_{30} . Give information of the reverberation time based on the sound decay and are derived from the sound decay curve between 5 dB and 15 dB, 25 dB and 35 dB respectively below the initial level, see Figure 13.
- Energy ratios:
 - T_s , Centre time, is the time of the centre of gravity of the squared impulse response.
 - C_{80} , Clarity, is the logarithmic early (first 80 ms) to late arriving sound energy ratio, see Figure 13.
 - D_{50} , Definition or “Deutlichkeit” is the early to total sound energy ratio.
- The equivalent constant A-weighted sound pressure level, L_{Aeq}
- The maximum A-weighted sound pressure level with time weighting F, L_{AmaxF}
- The peak C-weighted sound pressure level, L_{Cpeak}

These results represent a large amount of data and graphs and some of them are also correlated, so only the most interesting will be shown in this report.

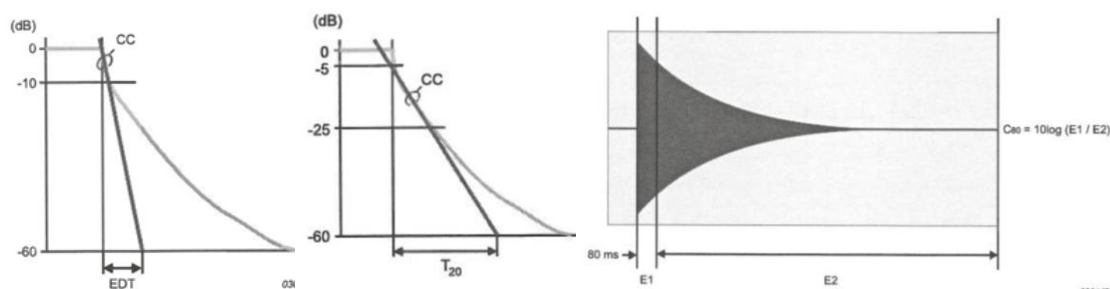


Figure 13
EDT, T_{20} and C_{80} illustrated by drawings from the Brüel & Kjær Dirac manual

6.1.1 Frequency responses

The frequency characteristics can be deduced from both the pink noise signals and from the Dirac signals. In average there is a good agreement between the two methods as illustrated in the measurements from Gimle, Figure 14. The curves measured in each of the positions illustrate the variations of the characteristics at different places in the venue.

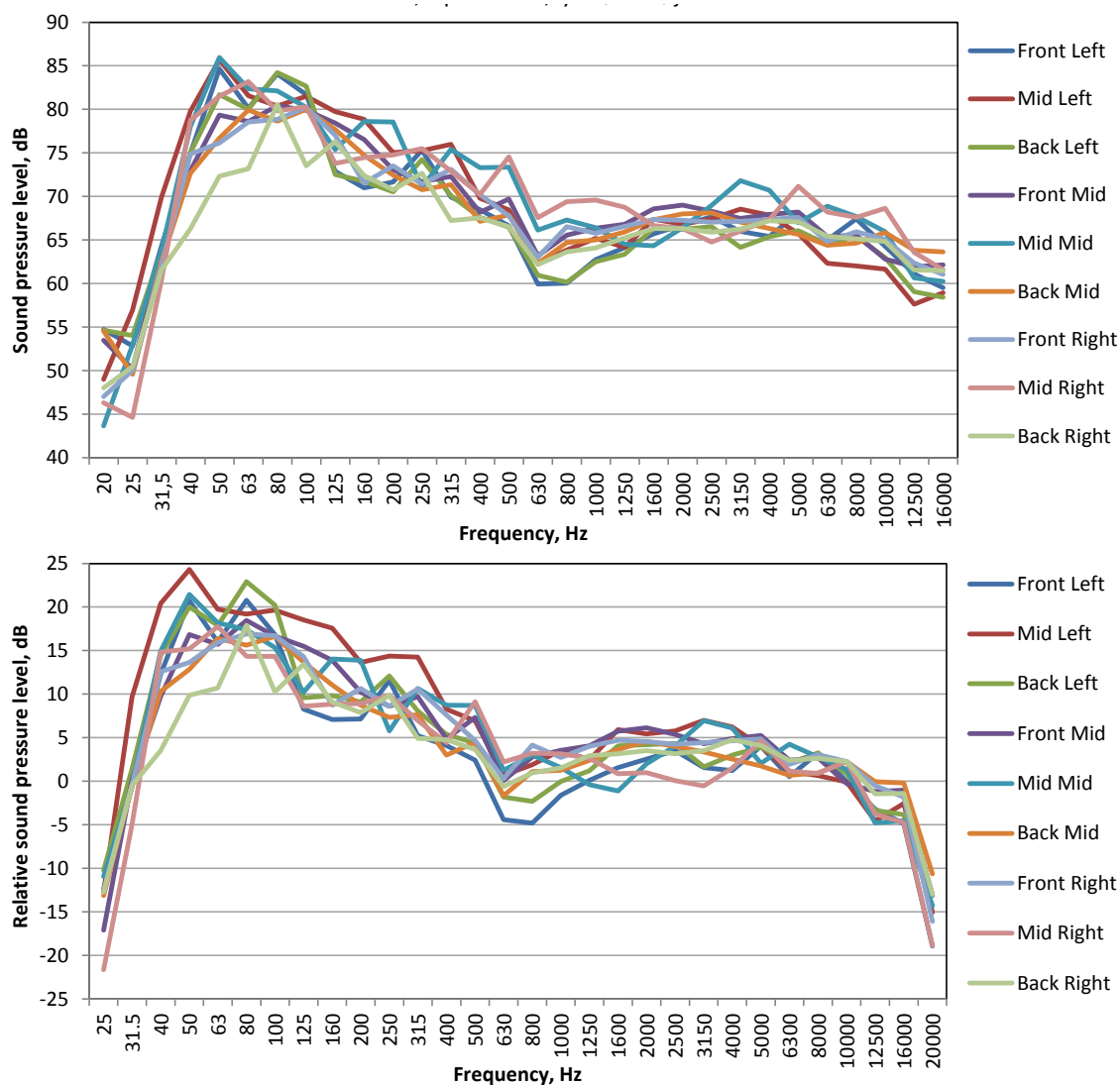


Figure 14

Gimle - frequency characteristics at the indoor venue. The upper graph is based on the pink noise measurements and the lower graph is based on the Dirac measurements.

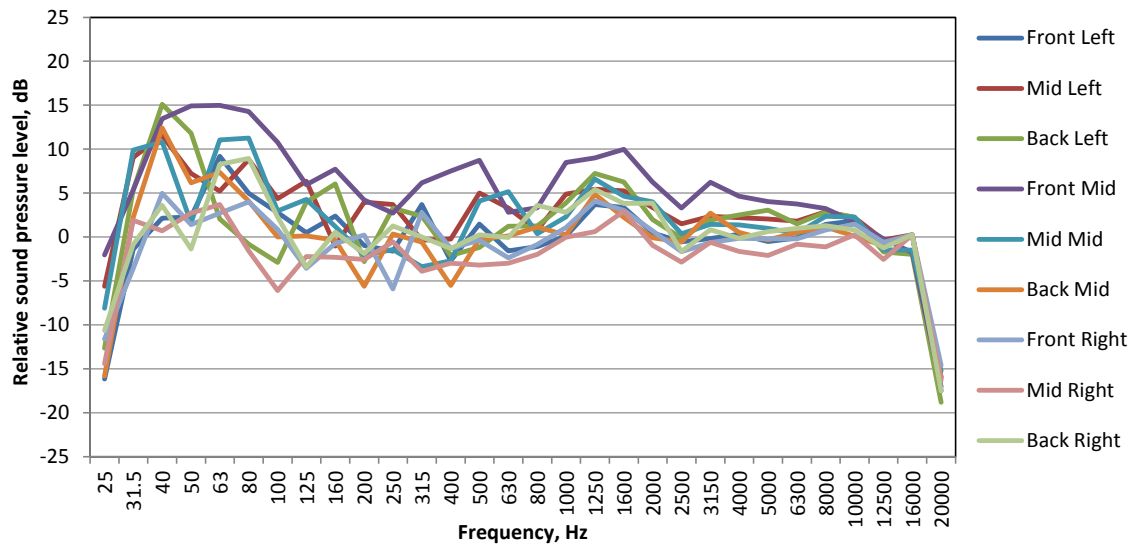


Figure 15
Kulturstationen - frequency characteristics at the indoor venue. The results are based on the Dirac measurements.

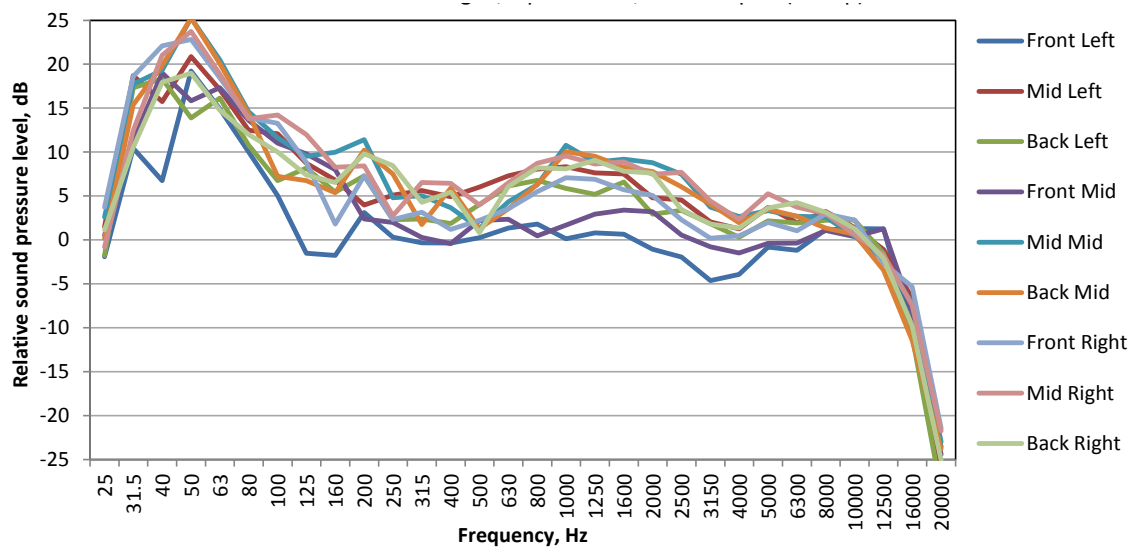


Figure 16
Forbrændingen - frequency characteristics at the indoor venue. The results are based on the Dirac measurements.

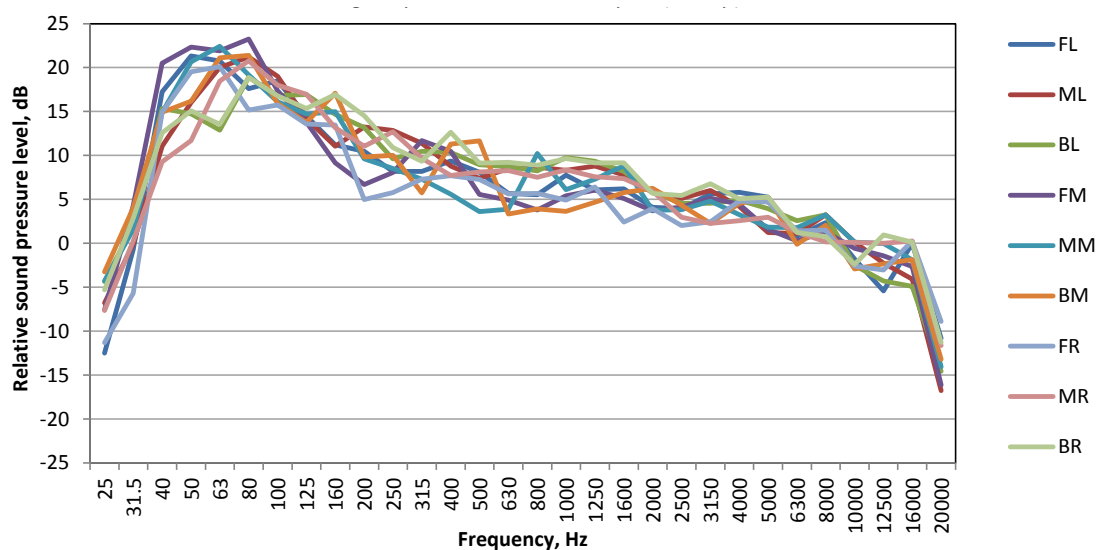


Figure 17

Store Vega - frequency characteristics at the indoor venue. The results are based on the Dirac measurements.

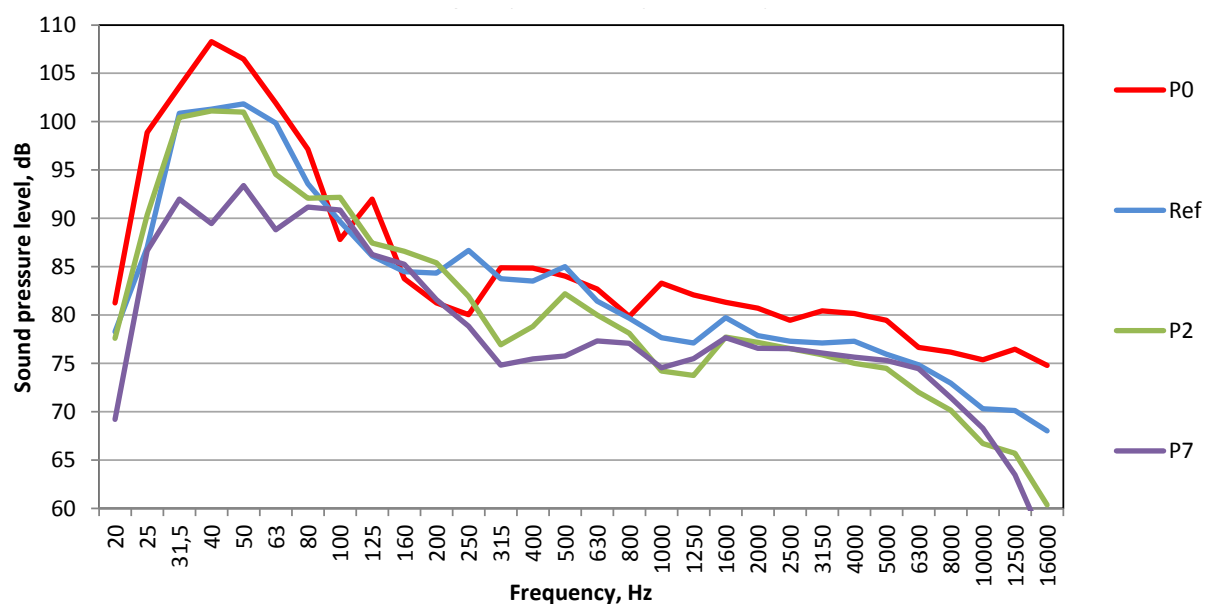


Figure 18

Orange scene at Roskilde Festival - frequency characteristics at the outdoor venue. The results are based on the Pink noise measurements. The placement of the measurement positions can be found in 12 – Appendix, Figure 44.

For the measurements at Orange scene, a misunderstanding during the measurement caused overload of some of the measurement systems during the Dirac sweeps, especially at frequencies below 100Hz for positions close to the stage. Therefore not all results for Orange scene based on the Dirac measurements are reliable. The frequency characteristics shown in Figure 18 are based on pink noise signals and should be correct.

In general the curves in Figure 14 to Figure 18 show a bass boost below approximately 100 Hz and a light a steady slope towards higher frequencies. The only exception is Kulturstationen, Figure 15, which has a more flat characteristic.

The frequency characteristics for Cosmopol and Pavilion, Figure 19 and Figure 20, show that the two stages are very similar. An average boost of 10-15 dB is seen between 30 and 80 Hz for both stages. This boost is most evident at the centre front and mid positions (HD 1,2 and HD 2,2). For Cosmopol, the centre front position (1,2) has a very high bass boost of 6 dB more than the average of all positions. The frequency responses on the two stages show very similar results, a difference of less than 6dB anywhere in the audible spectrum.

It is worth to note that the sound engineer working with the mixer settings at each concert can change the frequency spectrum significantly, during the concert.

The treble range drops with a steady slope to around -10dB (relative to the low midrange) at 16 kHz independent of position and stage. This setting will avoid the sound to be perceived as sharp or uncomfortable at the relatively high sound pressure levels during concerts.

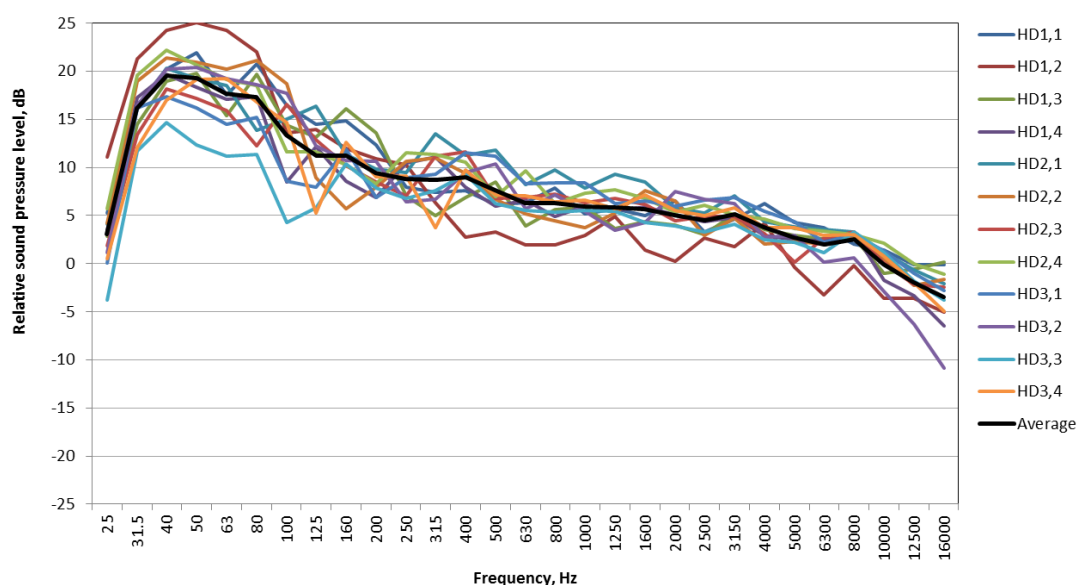


Figure 19
Cosmopol - frequency characteristics in 12 measuring positions at the tent venue. The results are based on the Dirac measurements.

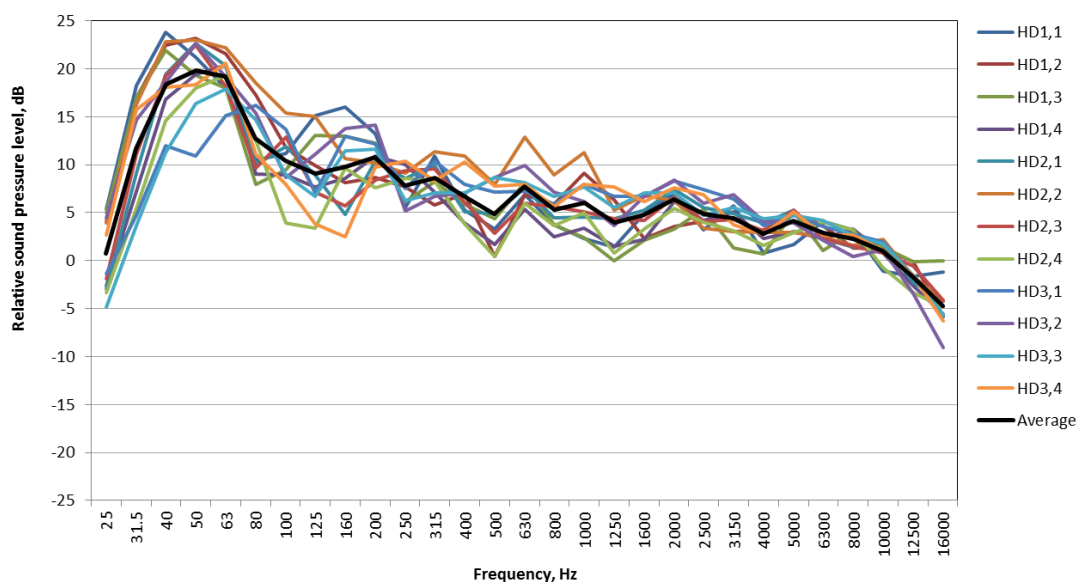


Figure 20
Pavilion - frequency characteristics in 12 measuring positions at the tent venue. The results are based on the Dirac measurements.

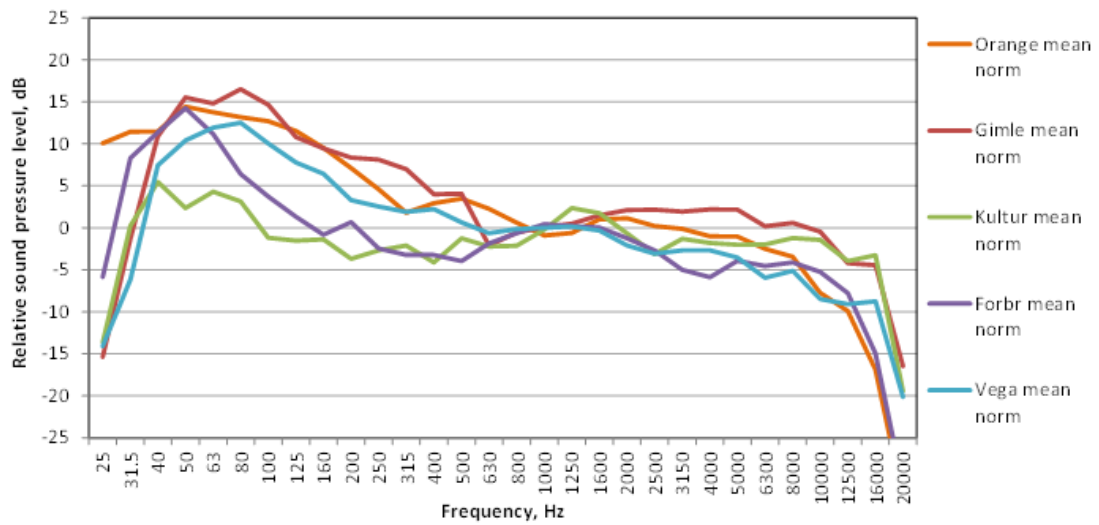


Figure 21

Average frequency characteristics for all positions for each of the venues listed in the legend. The results are based on the Dirac measurements. Please note that the curve for Orange scene is wrong below 100 Hz due to overload. According to Figure 18 it should also have the typical boost below 100 Hz as many of the other curves.

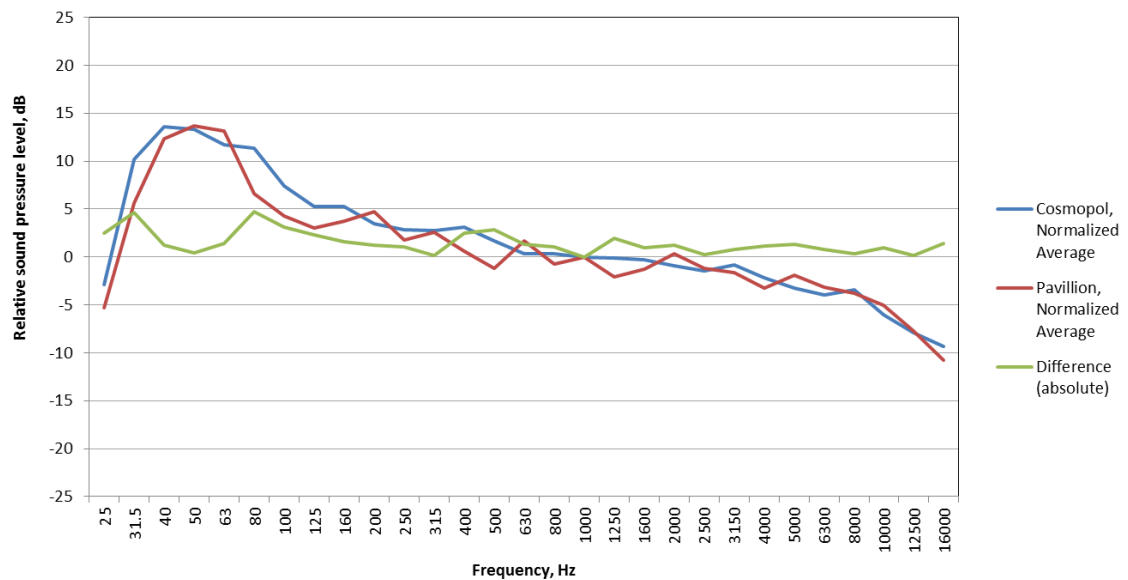


Figure 22

Cosmopol and Pavillion - Frequency spectrum comparison between averages. Normalized to 0dB at 1 kHz. The green curve is the difference.

From the indoor venues in Figure 21 (all except Orange) it is seen that Gimle has the “heaviest bass below 100-200 Hz, while Kulturstationen has the most flat frequency response.

It is also seen that the Cosmopol and Pavillion are very similar. The bass boost for these tent venues are located below 80 - 100 Hz. The differences in the type music played on each of these of stages could be an explanation for the slightly wider bass boost of the Cosmopol stage, compared to Pavillion (peaks at 31.5 and 80Hz for the absolute difference curve on Figure 22). Pavillion is an all-purpose stage, playing very varying types of music, where Cosmopol is primarily focused on bass-heavy electronic music.

6.1.2 Reverberation related parameters

Many of the reverberation related parameters EDT, T_{10} , T_{20} , T_{30} , T_s , C_{80} and D_{50} correlate positively or negatively. From a correlation matrix among these it was found that EDT, T_{20} and C_{80} were the least correlated, so they will be used for the further analysis.

The measurement results for EDT are shown in Figure 23. It is seen that Gimle has the highest EDT at low frequencies and that Vega has a generally high EDT. Kulturstationen has the lowest EDT. It is also seen, that the two tent venues Cosmopol and Pavilion has a very high EDT in the mid-frequency range.

The same pattern as mentioned above is seen for T_{20} in Figure 24

From Figure 25 it is seen that for all indoor venues the clarity C_{80} is decreasing towards the lower frequencies, Gimle has the steepest slope. Kulturstationen has the highest clarity while Vega has the lowest. For the tent venues the clarity is good at low frequencies, but low in the mid frequencies.

For the tent venues the reverberation time is higher at Cosmopol than on Pavillion, particularly between 125 and 4000Hz. The reverberation related values at both stages, will decrease in the high frequency range above 2-3 kHz when an audience is present at the stages. The clarity index (C_{80}) is affected by the reverberation time measures (T_s , $T_{10,20,30}$, EDT), and thus shows a similar trend, in being worse on Cosmopol than on Pavillion, and again particularly where the reverberation time is high (125-4000Hz). The same trend is seen on the D_{50} calculation.

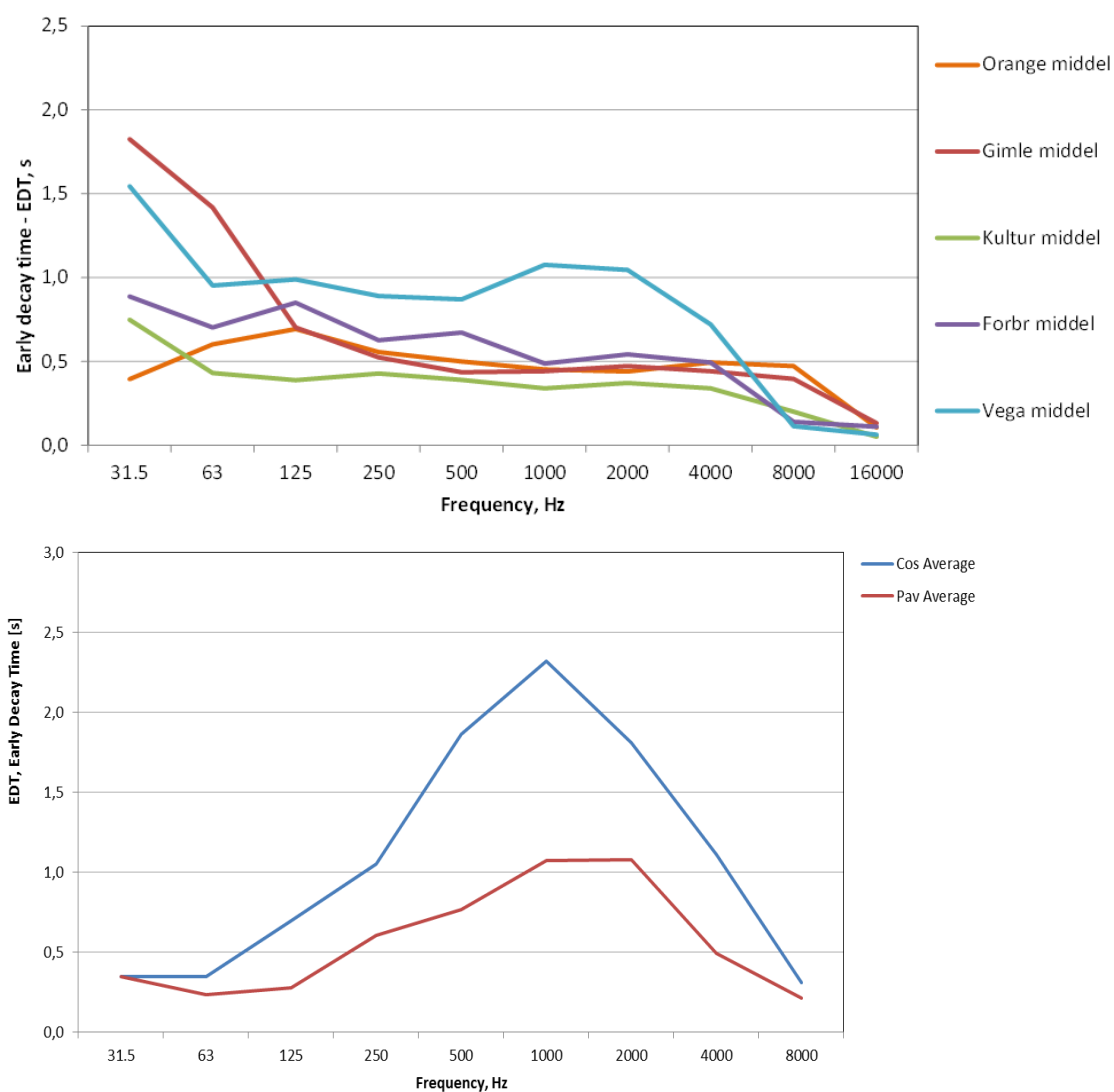


Figure 23

Average of Early Decay Time for all positions in the venues. The results for Orange scene at low frequencies are unreliable.

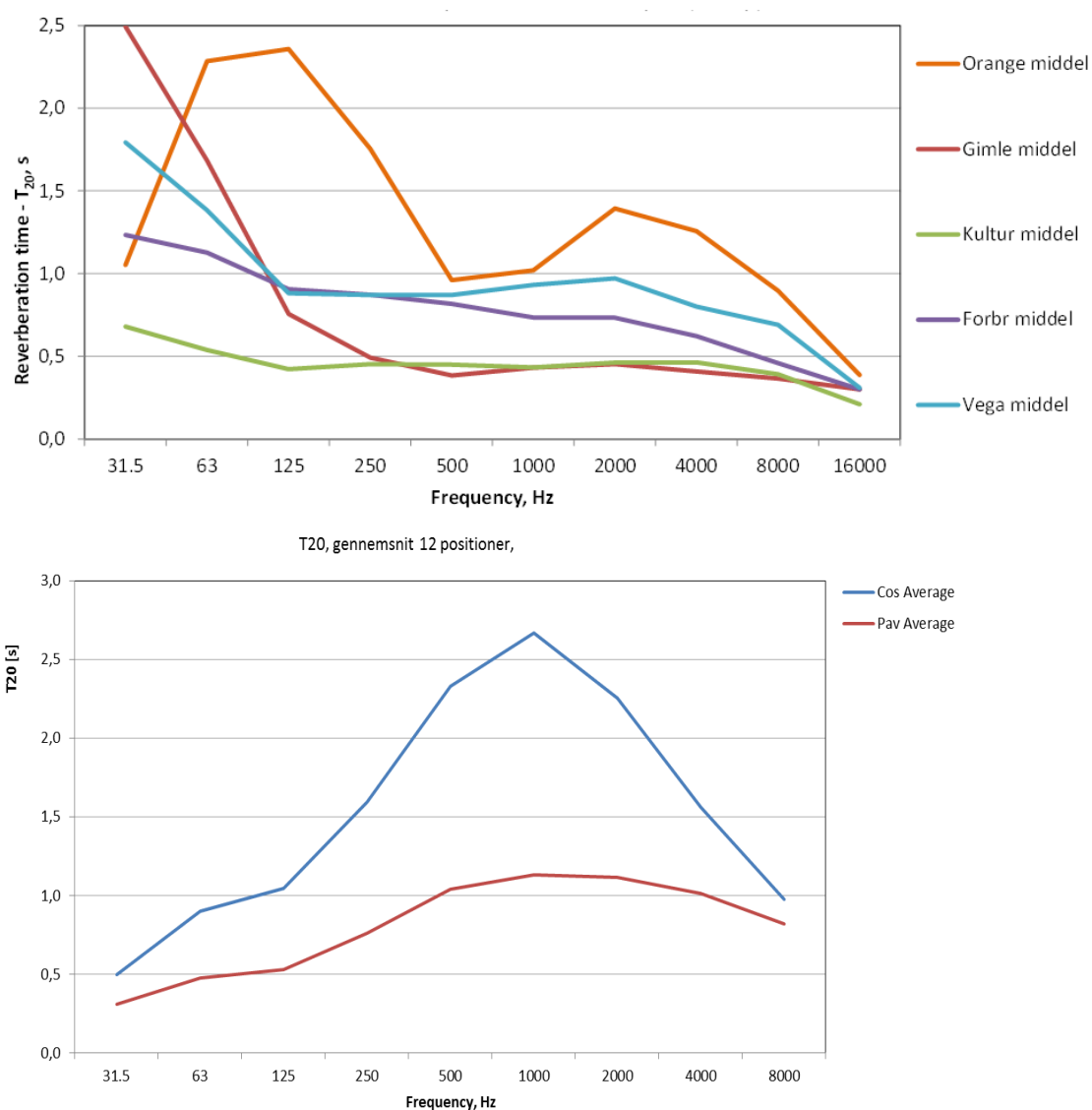
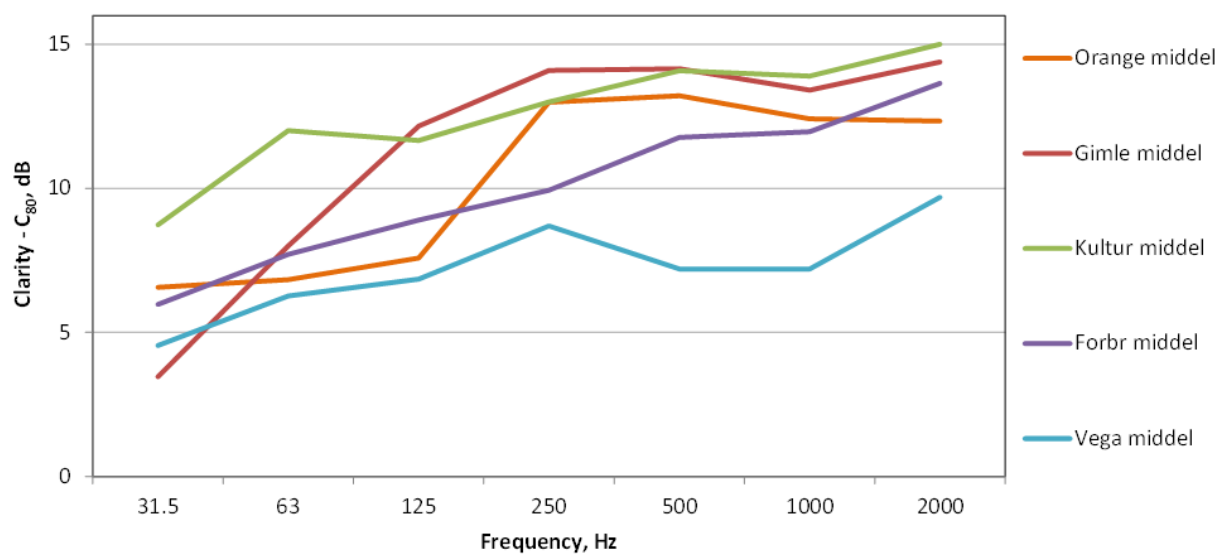


Figure 24

Average of T_{20} for all positions in the venues. The results for Orange scene at low frequencies are unreliable.



C_{80} , gennemsnit 12 positioner,

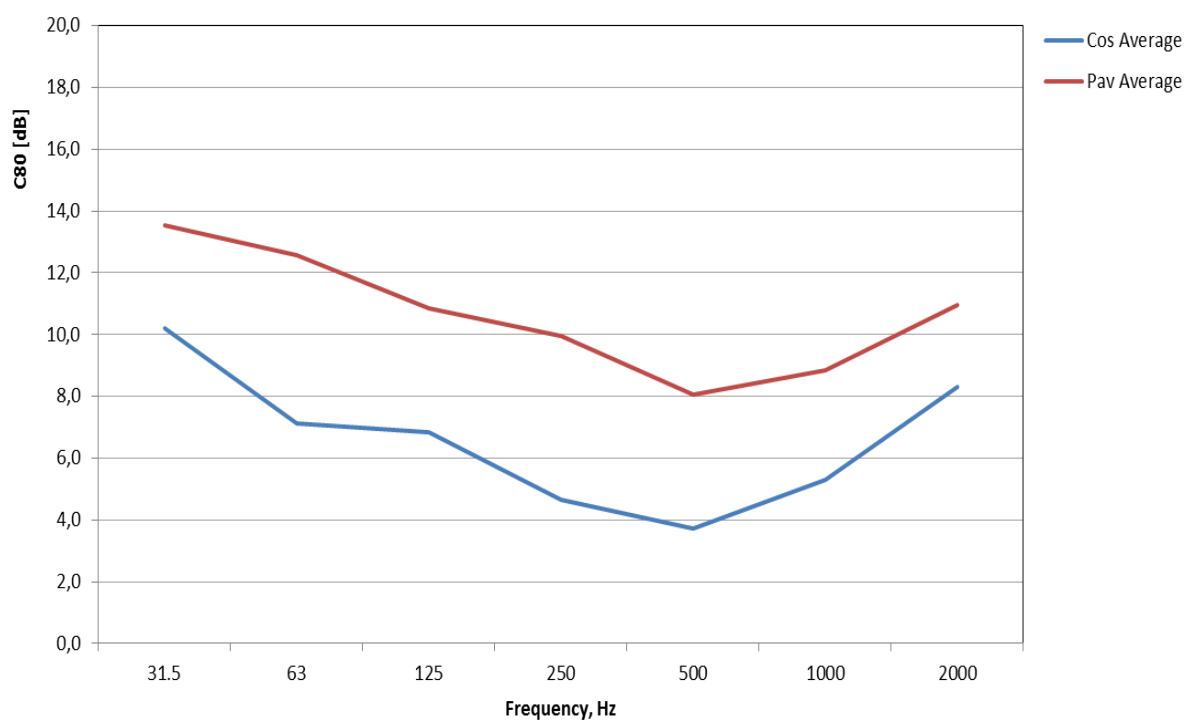


Figure 25

Average of the Clarity C_{80} for all positions in the venues. The results for Orange scene at low frequencies are unreliable.

6.1.3 Sound pressure levels during concerts

The sound pressure levels measured during the concerts can be seen in Figure 26. As the measuring microphone is placed close to the audience the audience sound is included in the measurements. Due to admittance problems during the concert no measurements were made at Orange scene.

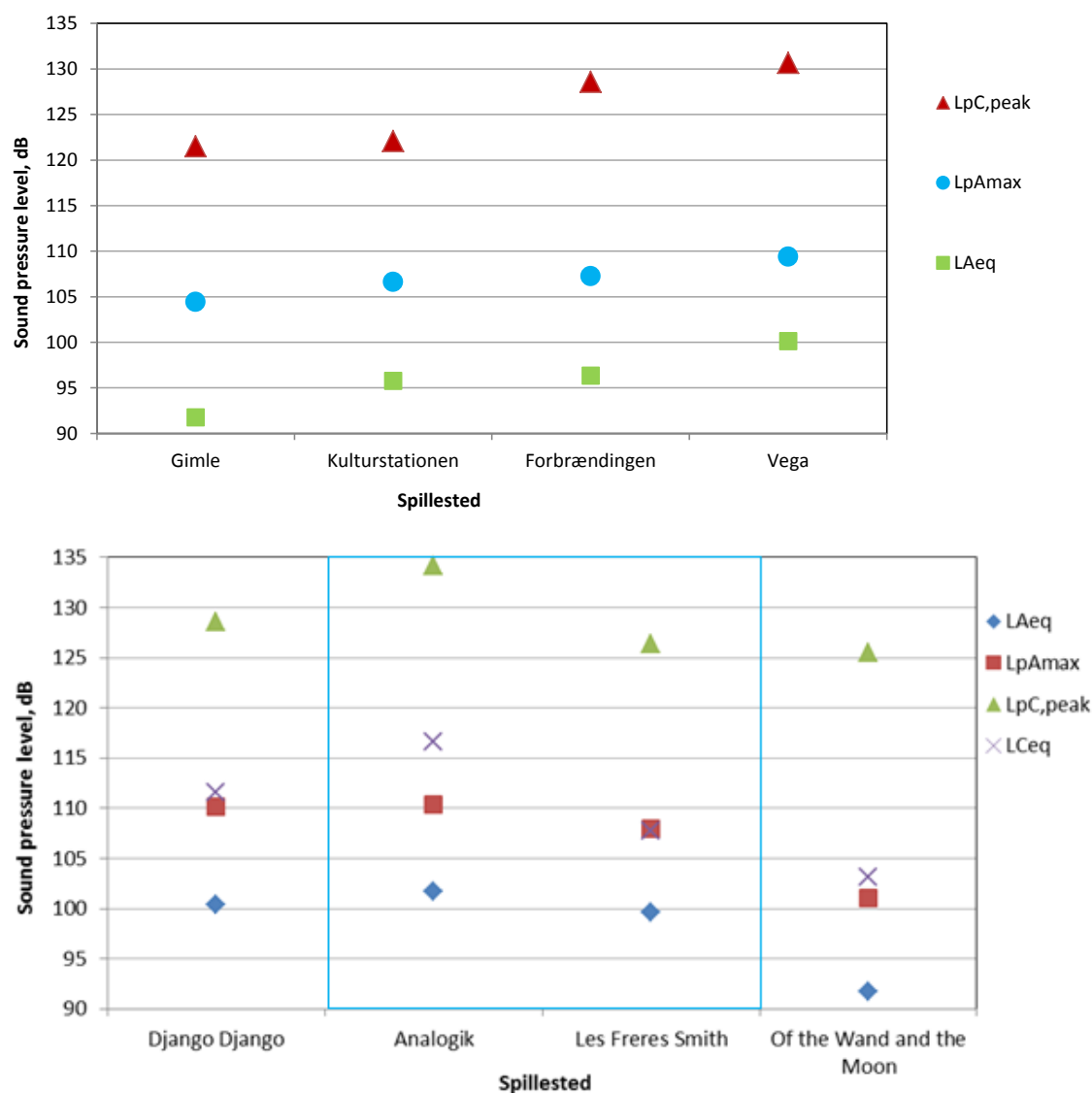


Figure 26

Max (L_{pCpeak}) and mean values (L_{Aeq} and L_{pAmaxF}) in 15 minutes periods of sound pressure levels during each concert. The blue square in the lower graph indicate the concerts at Cosmopol while the other measurements in the lower graph is from Pavilion.

Sound levels at each concert were measured at the two stages at Roskilde Festival 2012, see Figure 26. With the exception of the ‘Of the Wand and the Moon’ concert, the levels are very similar (L_{Aeq} within $\pm 1.5\text{dB}$). The concert which is quieter in terms of L_{Aeq} was performed by a band which plays a style of music which is quiet in itself, explaining the difference.

For peak value measurements ($L_{C, peak}$), a different picture is drawn – ‘Analogik’ has a peak sound pressure value which is significantly higher than all other concerts, but ‘Of the Wand and the Moon’ has comparable peak sound pressure to ‘Django-Django’ and ‘Les Freres Smith’.

Comparing the A-weighted measurements to the C-weighted measurements reveals that a large part of the sound power comes from the bass range. This aligns well with the measurements of the frequency spectra (where a 10-15dB boost is seen in the bass range – which is mostly ignored by the A-weighting filter.)

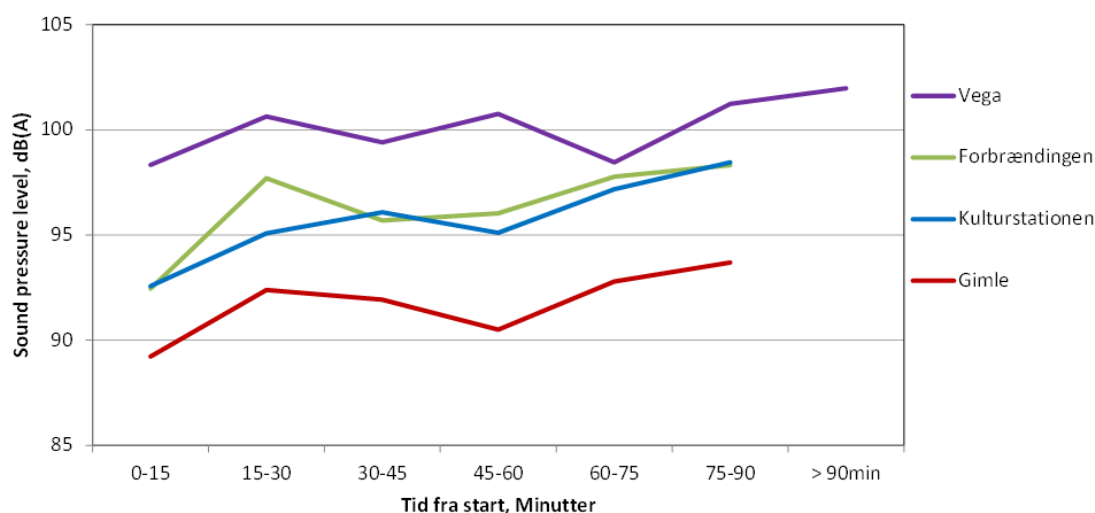


Figure 27

$L_{Aeq, 15 \text{ min}}$ at the mixer position for the four indoor concerts with Mikael Simpson

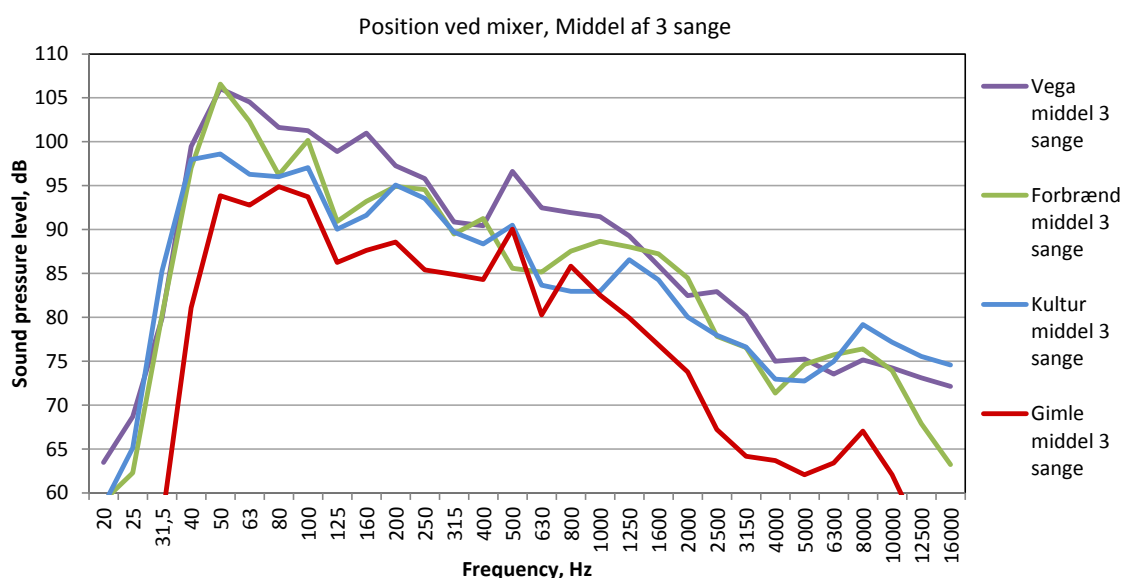


Figure 28

1/3 octave band spectra of the same three songs (Medicin - Lørdag aften – Mist dig selv i mig) at the mixer position for the four indoor concerts with Mikael Simpson.

From Figure 26 it is seen that for the same indoor concert at different venues there is an 8 dB span for the softest to the loudest venue. The average $L_{Aeq, 15 \text{ min}}$ values is in a range from 92 – 100 dB and the peak values $L_{pC, Peak}$ is in the range 122-130 dB.

For the two tent venues it is seen that the average $L_{Aeq, 15 \text{ min}}$ values is in a range from 92 – 102 dB and the peak values $L_{pC, Peak}$ is in the range 125-134 dB.

From Figure 27 it is seen that for the Mikael Simpsons concerts there is an increasing trend in the sound pressure levels for all four venues.

From Figure 28 the spectra for the same three songs at the indoor venues are measured. The relation between the venues differ slightly from the frequency characteristics of these, compare with Figure 21.

6.2 Metrics overview for the indoor venues

From the four indoor venues with the Mikael Simpsons concerts the main metrics for the venues and the concert are shown in Figure 29.

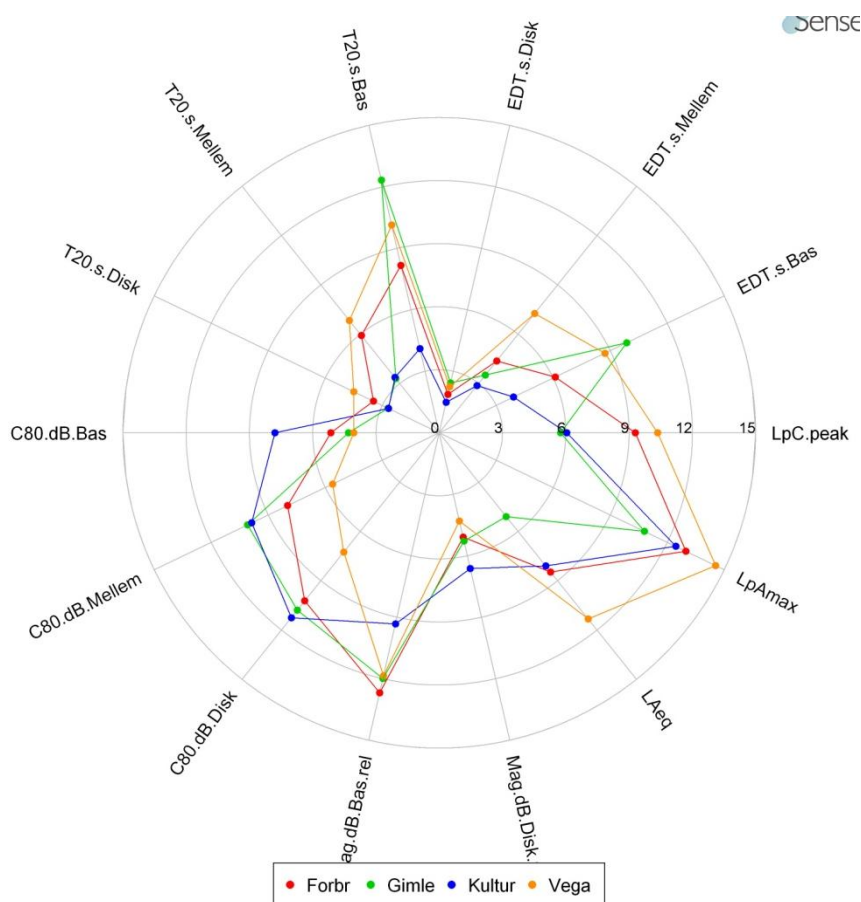


Figure 29

A relative profile plot of the physical characteristics measured as an average over all positions for each of the four indoor venues. All parameters are scaled to a 0-15 range for comparison. The underlying values can be found in Figure 21 to Figure 24.

From the frequency dependant measurements metrics the bass range (25-160 Hz third octave frequencies), the mid-frequency range (200-2000 Hz third octave frequencies) and the Treble/Disk range (over 3150 Hz third octave frequency) are shown separately. Mag Bass and Mag Treble/Disk are the levels relative to the mid-frequency range deduced from the frequency characteristics.

6.3 Perceptual assessments at the venues

6.3.1 Roskilde festival

The results at the Orange scene were obtained with two different bands at the same day.

As there were only two assessors in each position (for positions see 12 – Appendix) the variation in the assessments in each position is of the same magnitude or larger than the variations of the sound character for the different positions. Therefore an analysis of the variations between the positions did not show a meaningful picture.

From Figure 30 it is seen that the same sound system, the B-chain (see Figure 2) is assessed significantly different depending on the artists and sound engineer in the A-chain.

Based on listening to studio productions, the comments from the assessors and reviews of the concerts it is clear that the Kaizers orchestra has a more clear and tonal well balanced style than the Ravionettes, which is in accordance with the assessments shown in Figure 30.

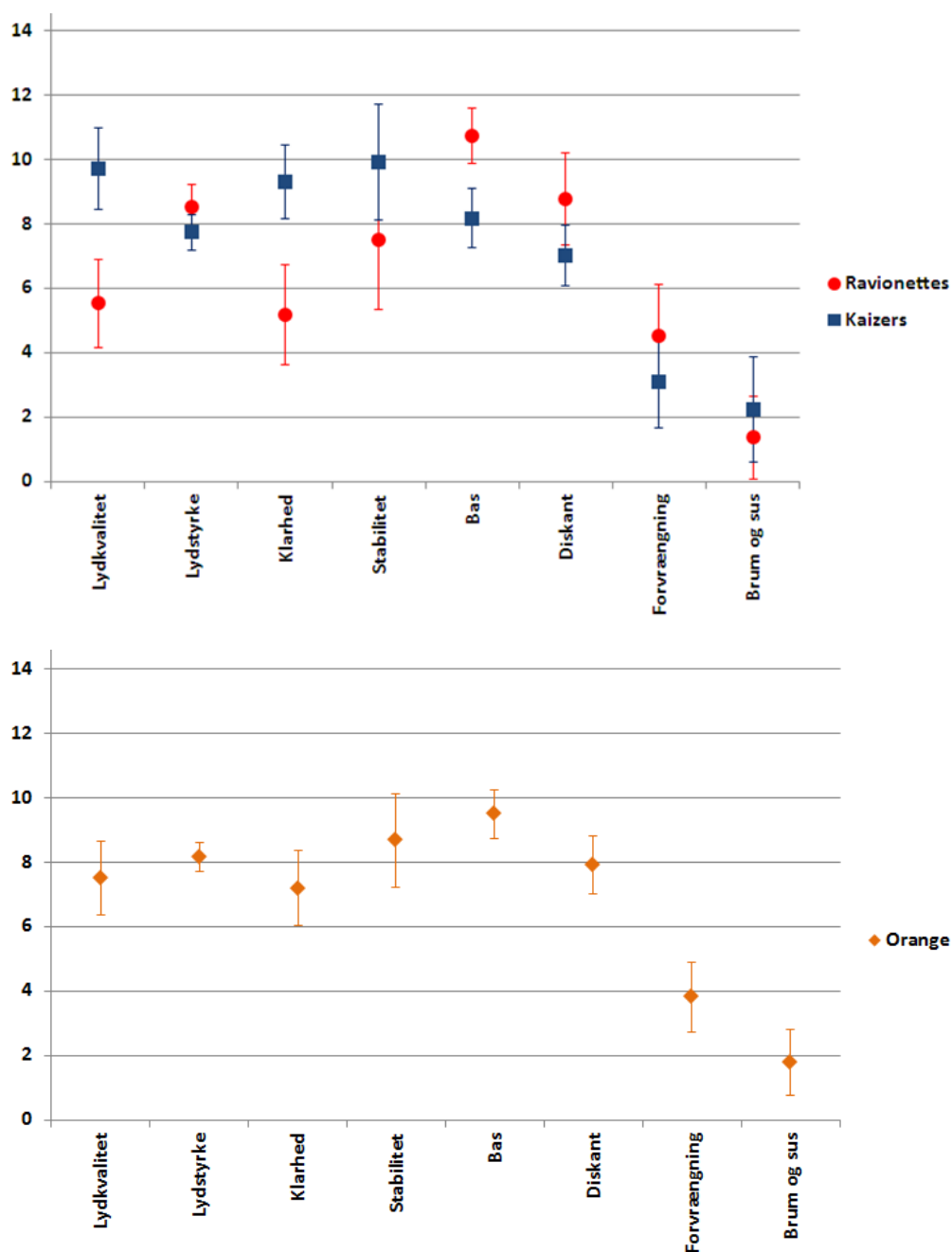


Figure 30

Assessment of the sound character for the Orange scene for two different bands at the same day. The lower graph shows the mean values. The assessment is the average of 18 assessors in 9 positions. The vertical bars indicate the 95% confidence intervals. If these intervals overlap, the results are, as a rule of thumb, statistically not significantly different. Translations: Lydkvalitet: Sound Quality. Brum og susen: Hum and Hiss. Forvrængning: Distortion. Diskant: Treble. Bas: Bass. Stabilitet: Stability. Klarhed: Clarity. Lydstyrke: Perceived loudness.

The mean assessments of the attributes as assessed by 14 expert assessors for the Cosmopol and Pavillon scenes are shown in Figure 31. The assessments were made on two successive days with one band on each stage each of the days.

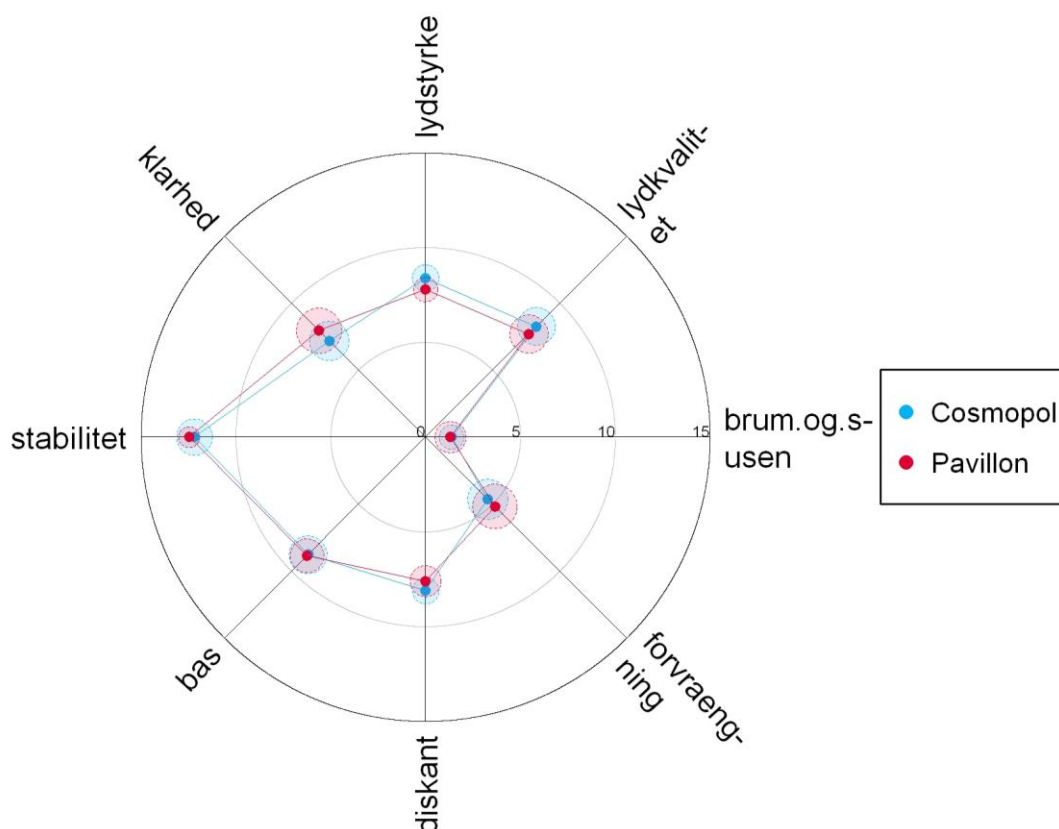


Figure 31

Profile plots for the Cosmopol and Pavillon stages, with 95% confidence intervals represented by circles. Translations: Lydkvalitet: Sound Quality. Brum og susen: Hum and Hiss. Forvrængning: Distortion. Diskant: Treble. Bas: Bass. Stabilitet: Stability. Klarhed: Clarity. Lydstyrke: Perceived loudness.

Looking at the profile plots for each stage, it is clearly seen that they have received very similar ratings. They are in fact not rated significantly different in any attributes.

This result is in accordance with the fact that most of the physical characteristics of the two stages are very similar. Based on the physical differences in decay time (EDT and T_{20}) and C_{80} (clarity) one would expect to see differences in the perceived characteristic Clarity,

which is not the case. The physical metrics are measured in the empty tents and the differences may be somewhat reduced by the added absorption caused by the presence of the audience.

Also the perceived characteristics for each of the concerts are very similar, see Figure 32. This could indicate that only small changes were applied by the mixing engineers from concert to concert.

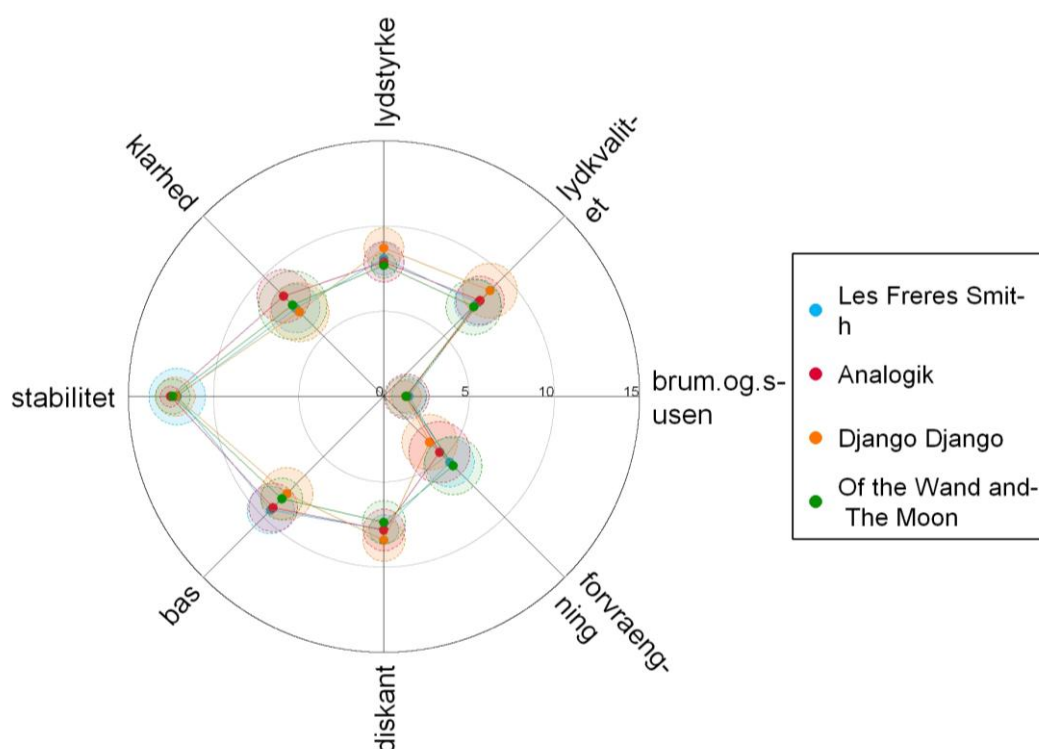


Figure 32

Profile plots for each band with 95% confidence intervals represented by circles. Translations: Lydkvalitet: Sound Quality. Brum og susen: Hum and Hiss. Forvrængning: Distortion. Diskant: Treble. Bas: Bass. Stabilitet: Stability. Klarhed: Clarity. Lydstyrke: Perceived loudness.

Each assessor was asked if they were using hearing protectors, this question gives interesting results, which are shown in Figure 33.

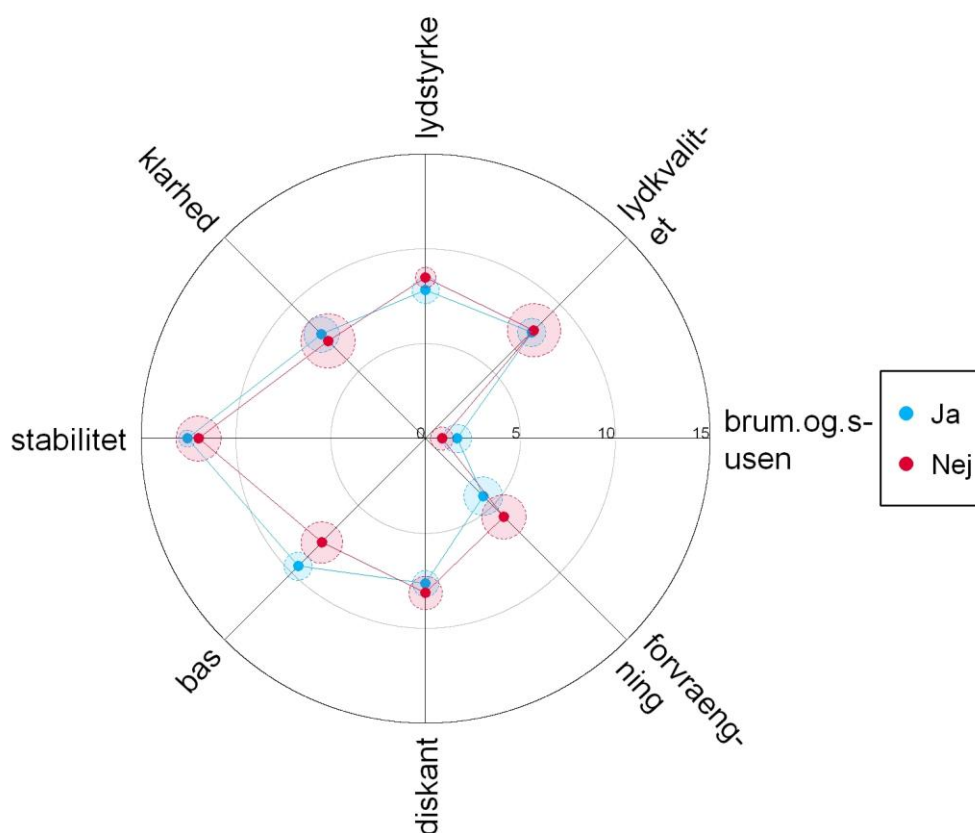


Figure 33

Profile plots for hearing protector question with 95% confidence intervals represented with circles. Translations: JA: With protectors. Nej: Without protectors. Lydkvalitet: Sound Quality. Brum og susen: Hum and Hiss. Forvrængning: Distortion. Diskant: Treble. Bas: Bass. Stabilitet: Stability. Klarhed: Clarity. Lydstyrke: Perceived loudness.

We note that bass is rated higher for the assessors wearing hearing protectors than the ones without. This can be explained by looking at the character of the ear plugs. The ear plugs remove more treble than bass, causing this shift in the relative perceived bass level. An interesting note is that the treble is not perceived differently.

The loudness is perceived very close to the same value, for both assessor groups (with / without) hearing protectors. This has the obvious explanation, that if the assessors felt the sound level was too high, they would use hearing protectors, and thus feel comfortable with the sound level. Finally it should be remembered that the middle of the scale is labelled: Tilpas (suitable/just about right).

Distortion is also perceived differently by the assessors with hearing protectors and the ones without. The less distortion for persons wearing hearing protectors may be explained by less distortion in the assessor's auditory systems.

It is also noteworthy, that the Sound Quality rating is not less for persons wearing hearing protectors.

To see if any of the perceptual attributes had a special significance for the perception of Sound Quality a correlation analysis was performed. The highest correlation was found for the attribute: Clarity. This draws towards the conclusion that clarity plays a big role in the overall Sound Quality rating.

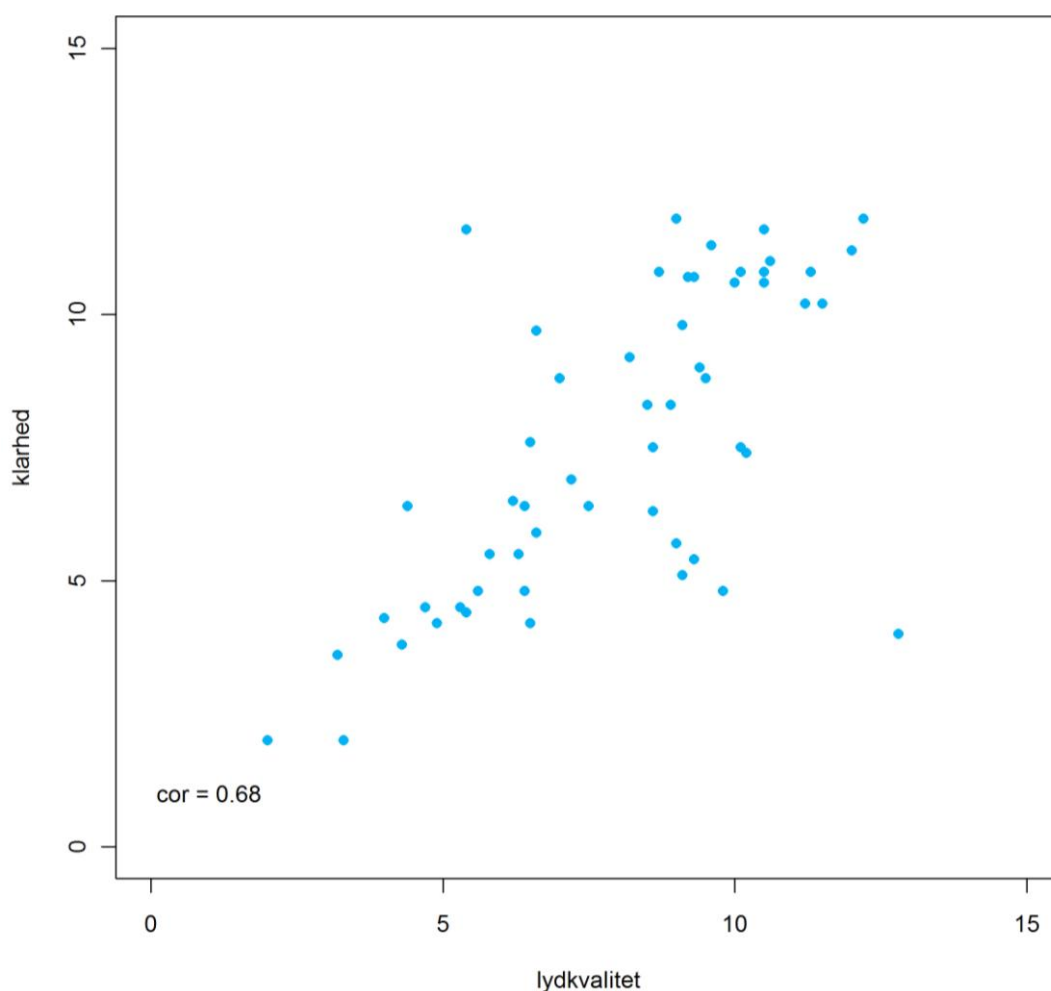


Figure 34

Scatter plot comparing the each assessors assessments of the Clarity attribute with the assessments of the Sound Quality attribute for the concerts at the Comopol and Pavilion stages. Translations: Lydkvalitet: Sound Quality. Klarhed: Clarity.

The large variation in the data is remarkable but it should be remembered that the results includes individual assessments of four different bands in two different venues with the assessors placed in 9 different listening positions at each venue.

Anyway a relatively high correlation is seen between the clarity and Sound Quality attribute.

It is interesting to see if there is any correlation between the attribute clarity and the physical metric for clarity, C_{80} . Figure 35 shows a scatter plot comparing the perceived clarity to C_{80} .

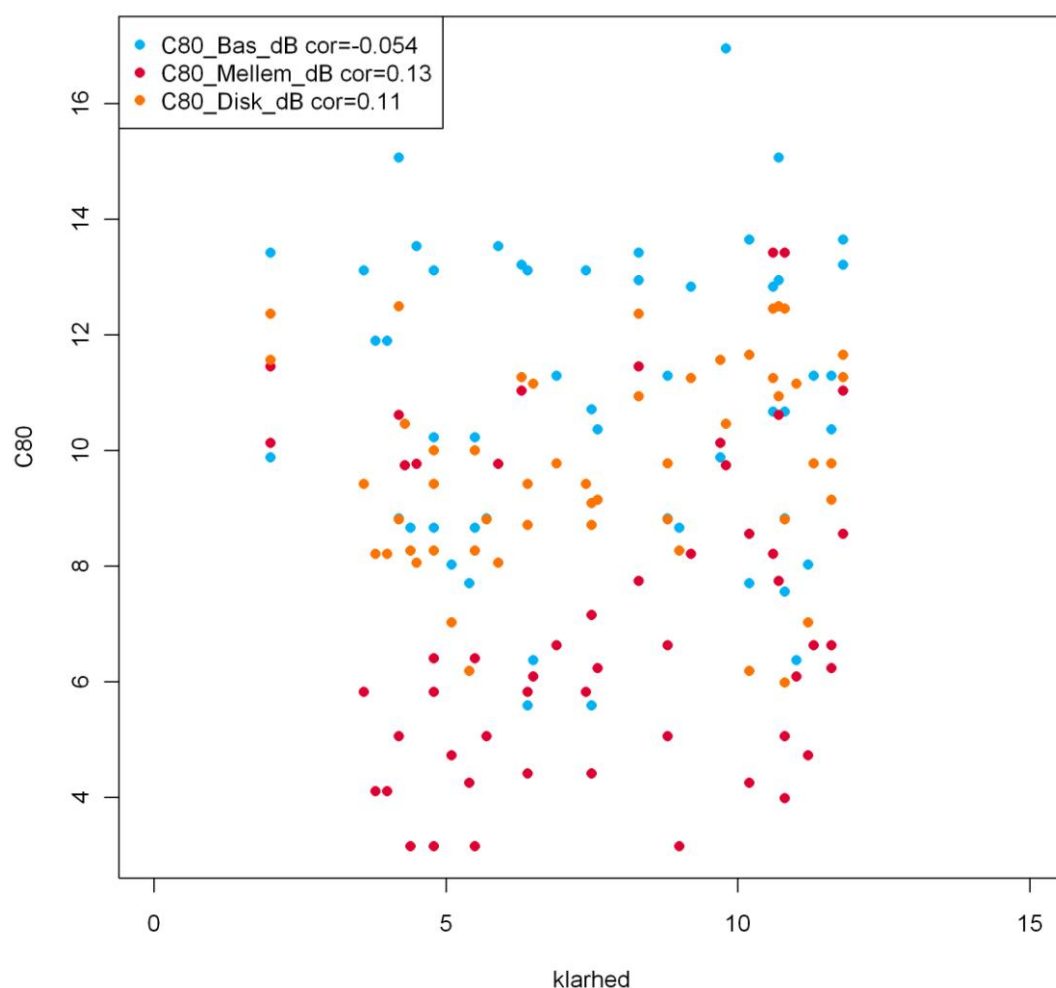


Figure 35

Scatter plot of physical C_{80} Measurements in 3 bands, treble, midrange and bass, compared to assessments of the Clarity (klarhed) attribute.

As the figure shows there are almost no correlation between the clarity attribute and the physical metric C_{80} .

6.3.2 Indoor venues

Perceptual assessments during live concerts were made at Mantziusgården with Tim Christen & band and at Vega with Mikael Simpson & band. The two concerts were assessed with several weeks interval.

Figure 36 shows the results. It is seen that there are no significant differences on any attribute between the assessments of the two events. The differences between the sound characteristics were apparently too small to be noted under these conditions.

It is also seen that the results are somewhat similar to the results from Cosmopol and Pavilion, Figure 31, when the confidence intervals are taken into account.

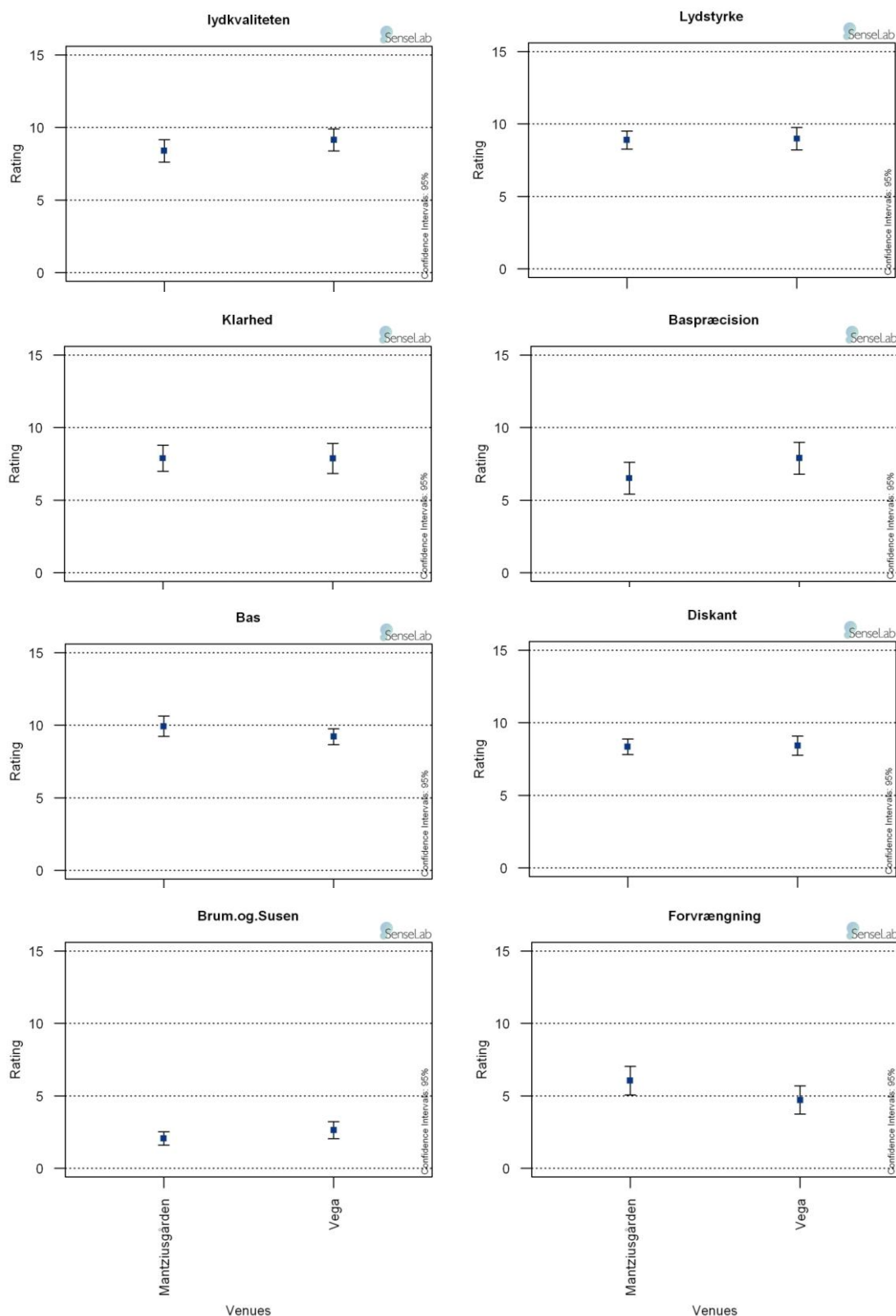


Figure 36

Assessment of two venues at live concerts. The assessments are made with an interval of some weeks with two different artists. Translations: Lydkvalitet: Sound Quality. Brum og susen: Hum and Hiss. Forvrængning: Distortion. Diskant: Treble. Bas: Bass. Stabilitet: Stability. Klarhed: Clarity. Lydstyrke: Perceived loudness.

6.3.3 Comparison of live assessments

In Figure 37 the mean values of the perceptual evaluations made by the expert assessors at the locations for live concerts for the tent venues Cosmopol and Pavilion and for the indoor venues Manziusgården and Vega are compared to the mean results from Orange scene. As there are no significant differences between Cosmopol and Pavilion on one side and Manziusgården and Vega on the other it is chosen to show the mean of tent venues and the mean of indoor venues.

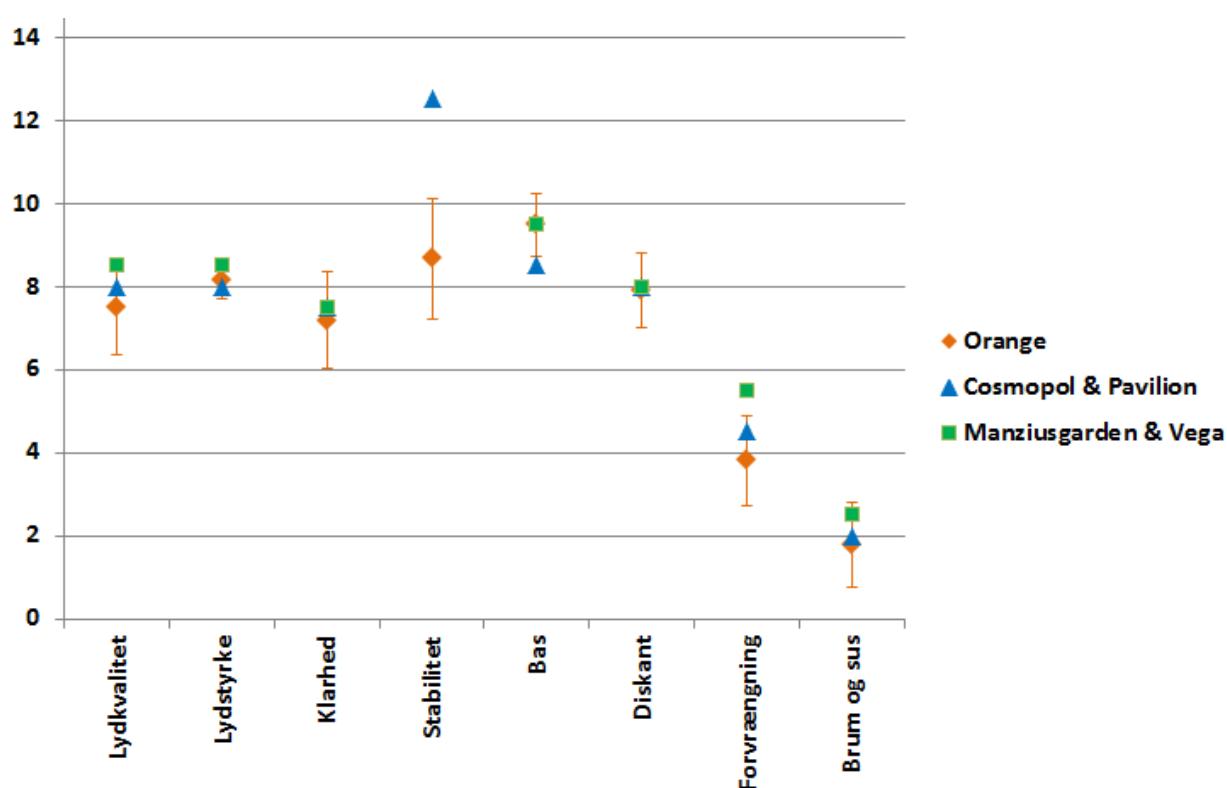


Figure 37

Average perceptual assessments made on location at live concerts. The data are a comparison of the mean data from Figure 30, Figure 31 and Figure 36. For overview only the confidence intervals for Orange scene is shown.

Except for a lower rating for the stability for Orange scene, where the audience area covers large distances in an outdoor setup, there are no significant differences for the perceptual assessments of any attribute for the different venue types.

This is a rather surprising result as the venues and concerts are different, the groups of assessors are not exactly the same and the assessments are made with months and years intervals.

A hypothesis for an explanation could be, that as the venues are all of good quality with expected good sound quality with loud music and solid bass and as the assessors have no direct possibilities of comparison the assessments are in accordance with the expectations for such venues. As there was no remarkable high or low quality events included, the differences between the venues were not large enough to be noted when there are large time intervals between the assessments.

6.4 Perceptual comparisons in the listening room

The perceptual assessment in the listening room, see clause 5.6, made it possible to make a direct comparison of the sound from the four venues with Mikael Simpson. As the acoustic memory is short, this is a much easier task for the 15 assessors than scoring the venues live with hours, days or weeks between the assessments.

It is seen from the results in Figure 38 that there is a clear and significant discrimination between the venues for the attributes: Sound Quality (Lydkvalitet), Clarity (klarhed) and Treble.

Forbrændingen seem to have the highest scoring on Bass precision and the lowest on Bass.

In general the scores on Bass precision seem to be “inverse” relative to the scores on Bass.

Figure 39 gives an overview of the same data as Figure 38.

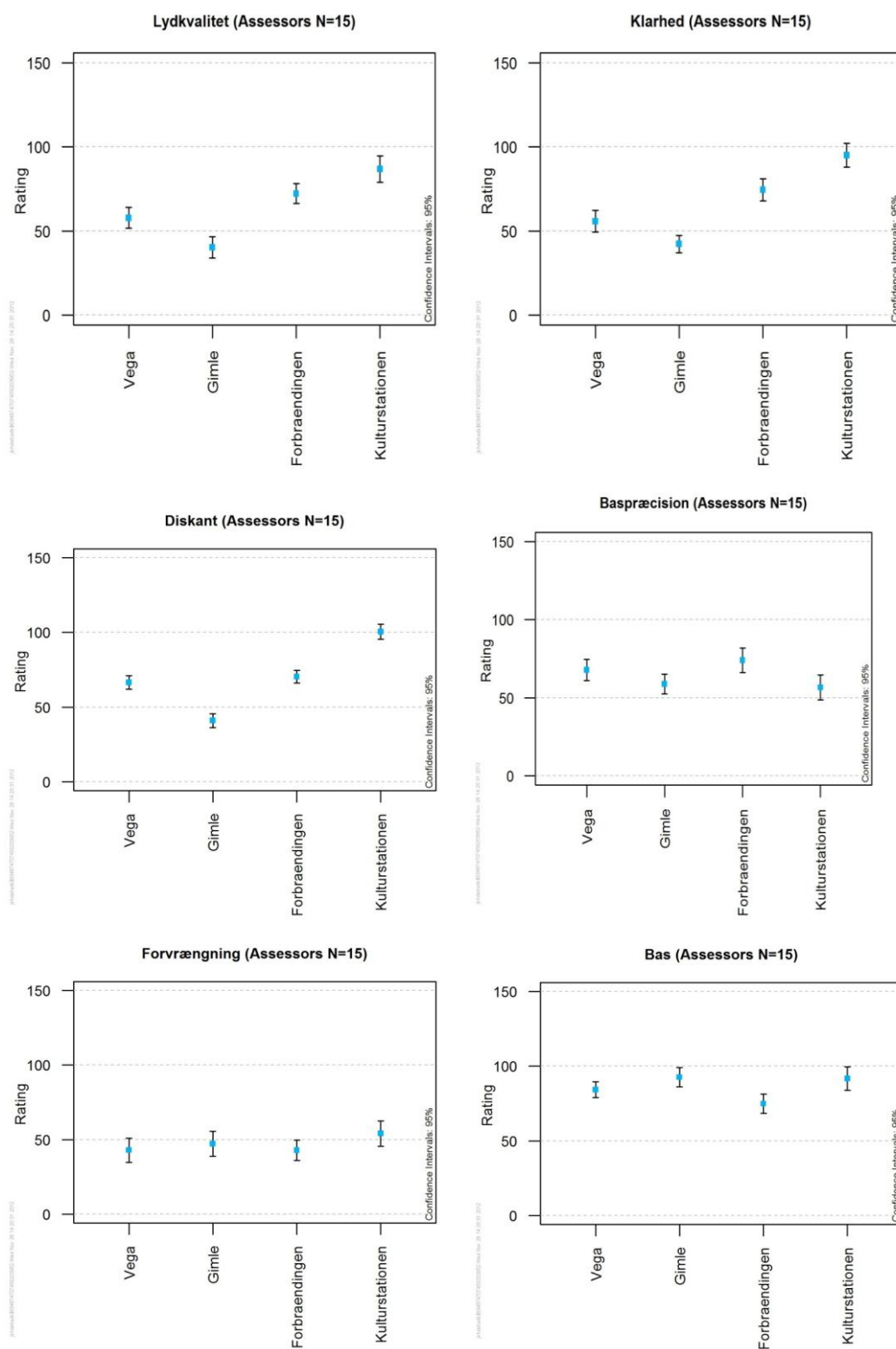


Figure 38
Assessments by direct comparisons of recordings at the four venues with Mikael Simpson.

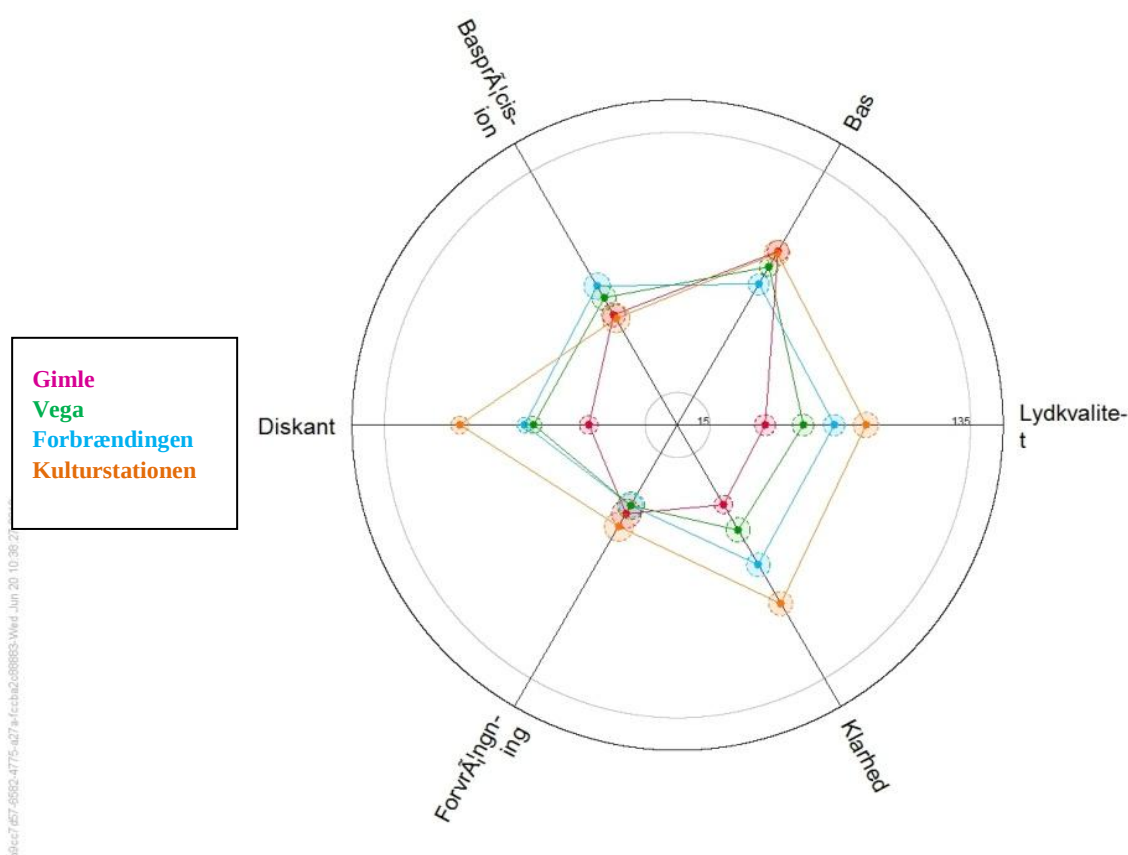


Figure 39

Spider plot giving an overview and comparison of the perceptual assessments of the binaural recordings from the four venues with Mikael Simpson. The circles indicate the 95% confidence intervals. Translations: Lydkvalitet: Sound Quality. Brum og susen: Hum and Hiss. Forvrængning: Distortion. Diskant: Treble. Bas: Bass. Stabilitet: Stability. Klarhed: Clarity. Lydstyrke: Perceived loudness.

6.5 Audience response

The response from the audience is based on the questionnaires collected just after the concert. The number of collected questionnaires is as follows:

- Gimle: 57 answers
- Forbrændingen: 61 answers
- Kulturstationen: 77 answers
- Mantziusgården: 44 answers
- Vega: 45 answers

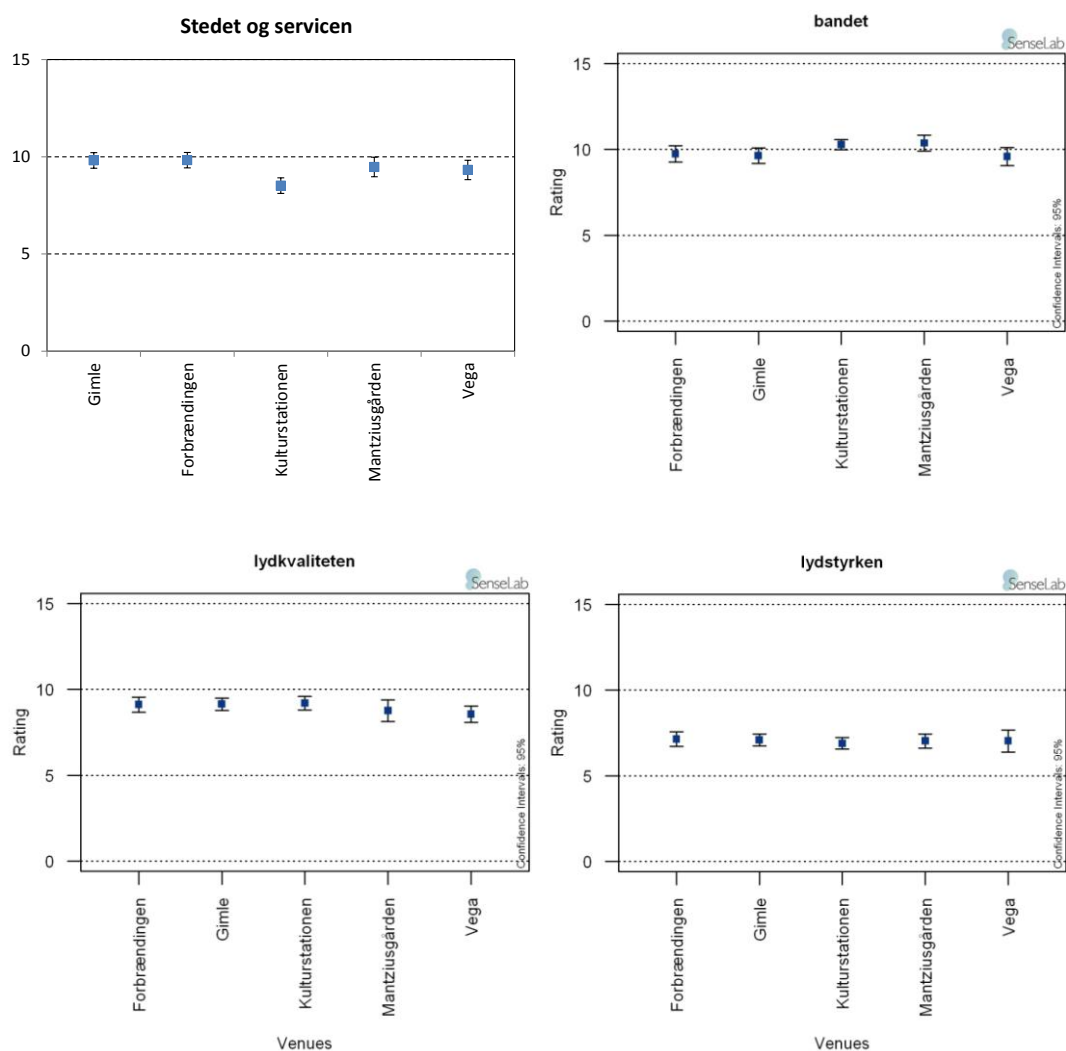


Figure 40

The results of the audience response from the indoor venues. The vertical bars indicate the 95% confidence intervals. Translations: Stedet og servicen: The venue and the service. Lydkvaliteten: The Sound Quality. Lydstyrken: The perceived loudness.

As it can be seen from Figure 40 the audience is satisfied above average with the venue service, the band and the Sound Quality and they find the perceived loudness suitable

There are no significant differences on the mean evaluations of the Sound Quality and the perceived loudness for the five different venues. For one exception this also holds for the venue service and the band. No bias effects from the liking of the service and the band to the evaluations of Sound Quality and perceived loudness can be seen.

7. Comparisons of domains

The original idea was to use variation (differences) in the data from the different venues to establish a connection between the physical domain i.e. the acoustic measurements, the perceptual i.e. the assessor evaluations and the affective domain i.e. the audience response.

As there is no variation in the average audience response for the different venues, see clause 6.5 it is not possible to establish a model between the perceptual and the affective domain.

As the mean values for the perceptual evaluations at the locations for the live concerts does not show any significant differences between the venues (see clause 6.3.3) it is not possible to establish a model between the perceptual and the physical domain based on these data.

The only usable data for this purpose is the perceptual comparisons of the binaural recordings of the four indoor venues with the Mikael Simpson Band, see clause 5.6 and 6.4. The main results are shown in Table 2. As mentioned in clause 6.2 the frequency ranges are defined as: Bass range (25-160 Hz third octave frequencies), mid-frequency range (200-2000 Hz third octave frequencies) and treble range (over 3150 Hz third octave frequency).

		Gimle	Vega	Forbraendingen	Kulturstationen
Perceptual	Sound Quality	40	58	72	87
	Clarity	42	56	75	95
	Bass	93	84	75	92
	Treble	41	66	70	100
	Basprecision	59	68	74	57
	Distortion	47	43	43	54
Physical	EDT Bass, s	1.32	1.16	0.81	0.52
	EDT Midrange, s	0.47	0.97	0.58	0.38
	EDT Treble, s	0.32	0.3	0.25	0.20
	T ₂₀ Bass, s	1.64	1.35	1.09	0.55
	T ₂₀ Midrange, s	0.44	0.91	0.79	0.45
	T ₂₀ Treble, s	0.36	0.60	0.46	0.36
	Bass, relative dB	9.0	8.7	10.4	3.6
	Treble, relative dB	-4.4	-6.4	-4.8	-1.8

Table 2

The mean values (over all assessors and three songs for each venue) of the perceptual results for the comparative listening test of binaural recordings (with subwoofer) of Michael Simpson Band and the main results of the physical measurements (mean values over 9 locations for each venue). The perceptual data is the mean assessments on perceptual scales of a total length of 150 units, see Figure 12. The middle of the scale is 75 units.

In Table 3 the correlation among the perceptual attributes and the physical metrics, see clause 6.2 are shown.

	Sound quality	Clarity	Bass	Treble	Bass precision	Distortion	EDT.s.Bass	EDT.s.Mid	EDT.s.Treble	T20.s.Bass	T20.s.Mid	T20.s.Treble	dB.Bass.rel	dB.Treble.rel
Sound quality	1,00	0,99	-0,22	0,97	0,03	0,47	-0,98	-0,27	-0,98	-0,98	0,00	-0,12	-0,61	0,61
Clarity	0,99	1,00	-0,12	0,96	-0,08	0,57	-1,00	-0,40	-1,00	-0,99	-0,14	-0,25	-0,67	0,71
Bass	-0,22	-0,12	1,00	-0,03	-0,97	0,73	0,13	-0,40	0,09	0,01	-0,76	-0,54	-0,64	0,48
Treble	0,97	0,96	-0,03	1,00	-0,14	0,58	-0,94	-0,21	-0,95	-0,98	-0,05	-0,09	-0,75	0,63
Bassprecision	0,03	-0,08	-0,97	-0,14	1,00	-0,86	0,08	0,56	0,11	0,18	0,85	0,67	0,75	-0,67
Distortion	0,47	0,57	0,73	0,58	-0,86	1,00	-0,58	-0,72	-0,60	-0,64	-0,81	-0,73	-0,93	0,94
EDT.s.Bass	-0,98	-1,00	0,13	-0,94	0,08	-0,58	1,00	0,45	1,00	0,98	0,18	0,30	0,65	-0,73
EDT.s.Mid	-0,27	-0,40	-0,40	-0,21	0,56	-0,72	0,45	1,00	0,46	0,39	0,89	0,98	0,45	-0,87
EDT.s.Treble	-0,98	-1,00	0,09	-0,95	0,11	-0,60	1,00	0,46	1,00	0,99	0,20	0,31	0,68	-0,75
T20.s.Bass	-0,98	-0,99	0,01	-0,98	0,18	-0,64	0,98	0,39	0,99	1,00	0,18	0,26	0,75	-0,74
T20.s.Mid	0,00	-0,14	-0,76	-0,05	0,85	-0,81	0,18	0,89	0,20	0,18	1,00	0,95	0,56	-0,80
T20.s.Treble	-0,12	-0,25	-0,54	-0,09	0,67	-0,73	0,30	0,98	0,31	0,26	0,95	1,00	0,44	-0,82
dB.Bass.rel	-0,61	-0,67	-0,64	-0,75	0,75	-0,93	0,65	0,45	0,68	0,75	0,56	0,44	1,00	-0,82
dB.Treble.rel	0,61	0,71	0,48	0,63	-0,67	0,94	-0,73	-0,87	-0,75	-0,74	-0,80	-0,82	-0,82	1,00

Table 3

Correlation matrix for the perceptual assessments (green text) of the recordings in the listening room and selected acoustic metrics (black text) for the venues with Mikael Simpson. Correlations above 0.7 are coloured red and correlations below -0.7 are coloured blue.

In the interpretation of the results it is important to note that the observations are based on four venues only and on the variation in the data which these venues represent. It should also be noted that the results in this clause is based on a comparison of acoustic (physical) measurements of the venues and on listening tests on recordings of a concert in these venues.

For one of the venues (Vega) Figure 41 shows the relations between assessments made on location during a live concert and on a binaural recording reproduced over headphones and a subwoofer of the same three songs from the same concert.

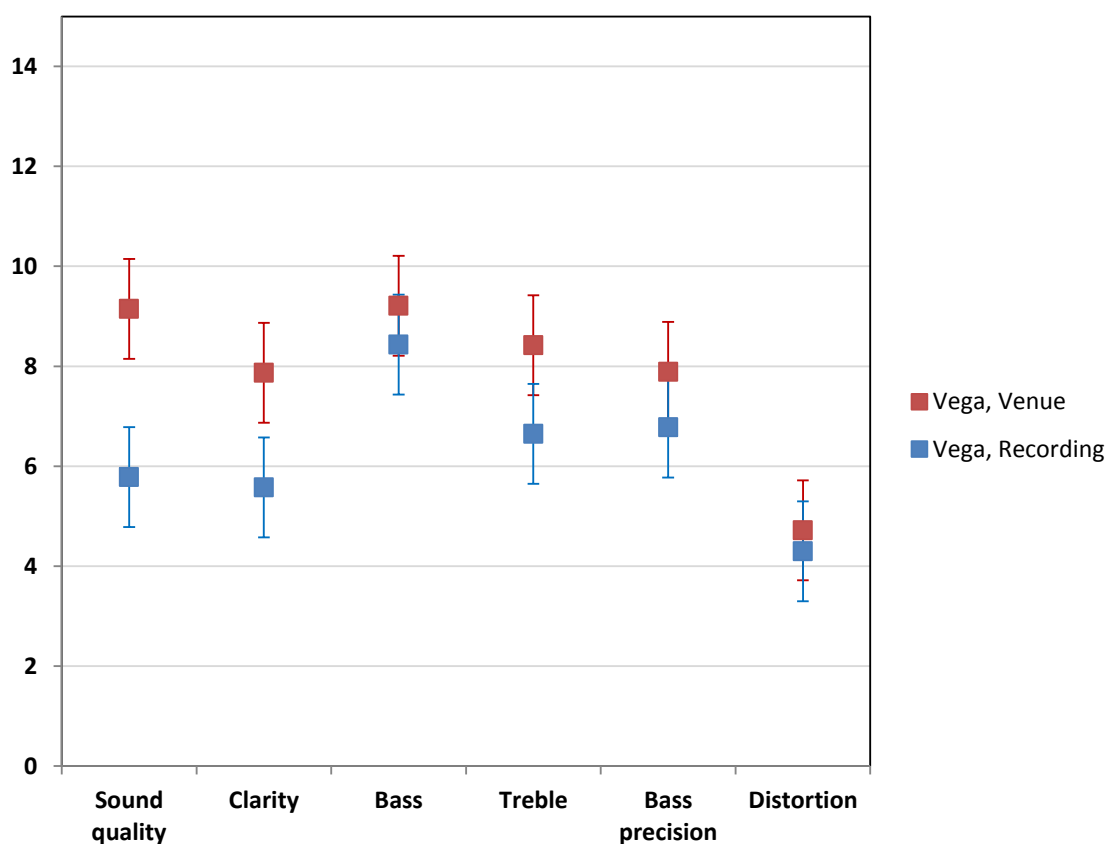


Figure 41

Comparison of the mean assessments of the perceptual attributes from the live concert (at the venue) and of the binaural recording with subwoofer in the listening room. It is the mean of the assessment of the same three songs by 8 assessors in the live situation and 15 assessors in the listening room.

From the figure it is seen that the only significant differences in assessments of the live situation and of the recording is on the overall Sound Quality and the Clarity. Both the Sound Quality and Clarity are significantly higher in the live situation. There may be two reasons for that. One reason may be that although it is binaural recordings made with high grade professional equipment presented over high quality headphones with a subwoofer for a solid bass reproduction you will perceive the sound more clearly with your own ears at the live event than though the ears of the Head And Torso Simulator used for the recordings. Furthermore you have support in the acoustic perception of the concert from the visual perception in the live situation. Another reason may be, that when you sit in a listening room with headphones your expectations may be more related to the higher clarity that you are used to from studio recordings or close microphone technique used in recordings from live concerts. With these remarks in mind we will take a closer look at the results.

From Table 3 it can be seen that there are high positive correlations between the perceptual assessments of Sound Quality, Clarity and Treble. This means that if the assessors give high scores on Clarity or Treble they will also give high scores on Sound Quality. This was also found for the assessments on location for Cosmopol and Pavilion, see Figure 34.

The definitions of these three attributes are (see clause 10 Appendix):

Sound Quality: Your overall assessment of the sound quality

Clarity: Is the reproduction distinct, clear and detailed without time delays and/or echoes? Is the reproduction of instruments and vocal precise and distinct? The opposite of clearness is: Muddy, confluent with echoes or excessive reverberation.

Treble: The relative intensity of the treble, i.e. the bright tones (high frequencies) e.g. cymbals, s-sounds (hissing sounds). A neutral Treble should be placed on the middle of the scale.

The middle of the scale is 75 units.

It can also be seen that within the range of EDT for the bass of 0.52 to 1.32 s the smallest EDT gives the highest assessment of the Sound Quality. The same holds for the EDT of the treble in the range 0.2 to 0.32 s. Whether the latter is a casual result or a consequence of the high correlation between bass and treble EDT's for the four venues is not known.

There is a very high negative correlation between the Clarity and the EDT of the bass and the treble.

It is also seen that the Sound Quality is somewhat negatively correlated with the relative level of the bass and somewhat positively correlated with the relative level of the treble and that the Clarity is positively correlated with the relative level of the treble.

From Figure 42 the relations between the perceived Sound Quality and different attributes and metrics are shown. As from the correlation matrix a clear relation between Sound Quality and Clarity, Treble, EDT for bass and treble and T_{20} for bass is seen.

It can also be seen that it is not the same relations that applies for the attributes Bass and Treble as for the physical metrics for bass and treble.

The perceived Sound Quality seem to increase with the bass precision and decrease with the bass except for Kulturstationen which breaks the pattern. With only four data points the previous statement should be taken with reservation.

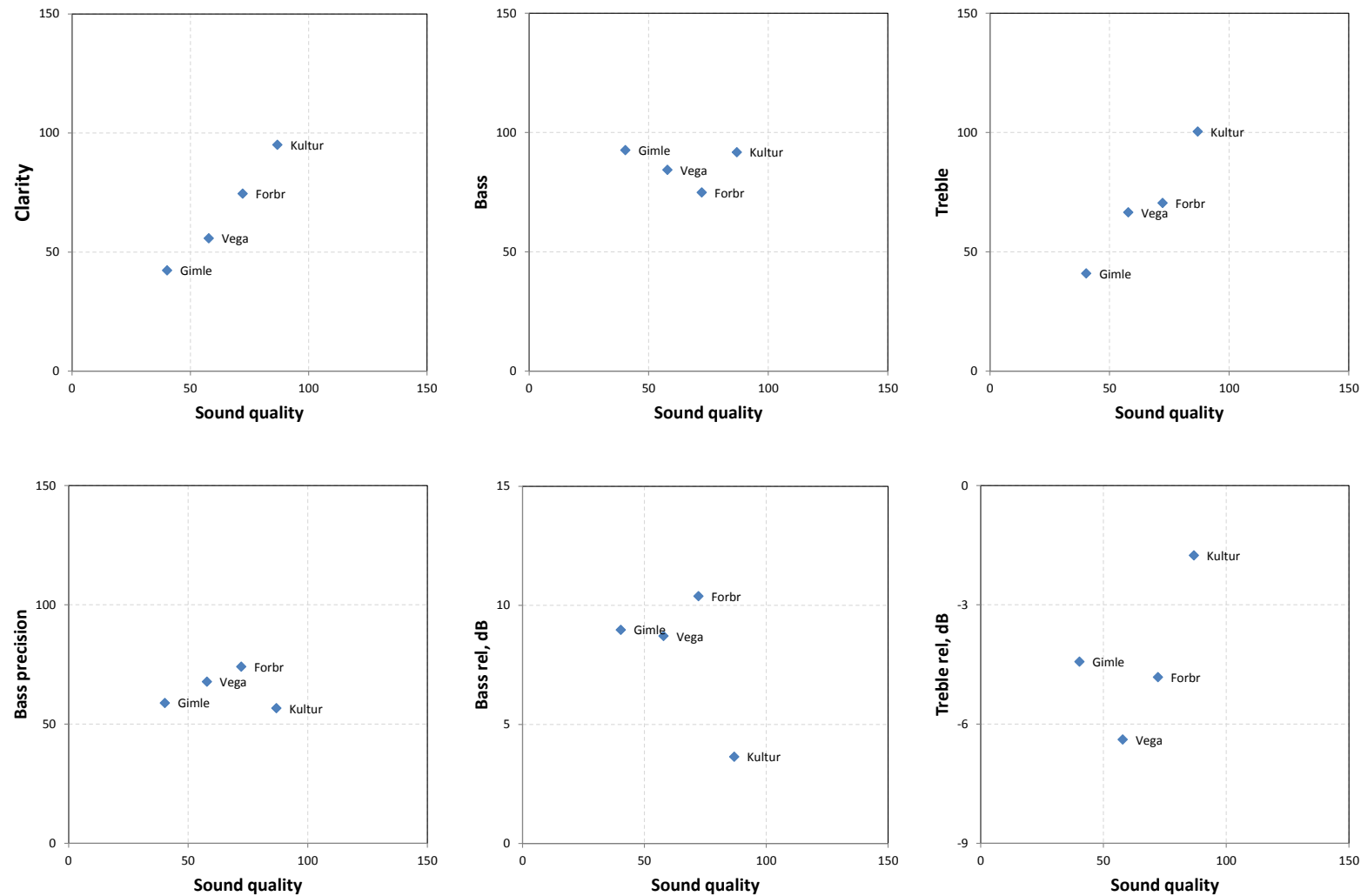
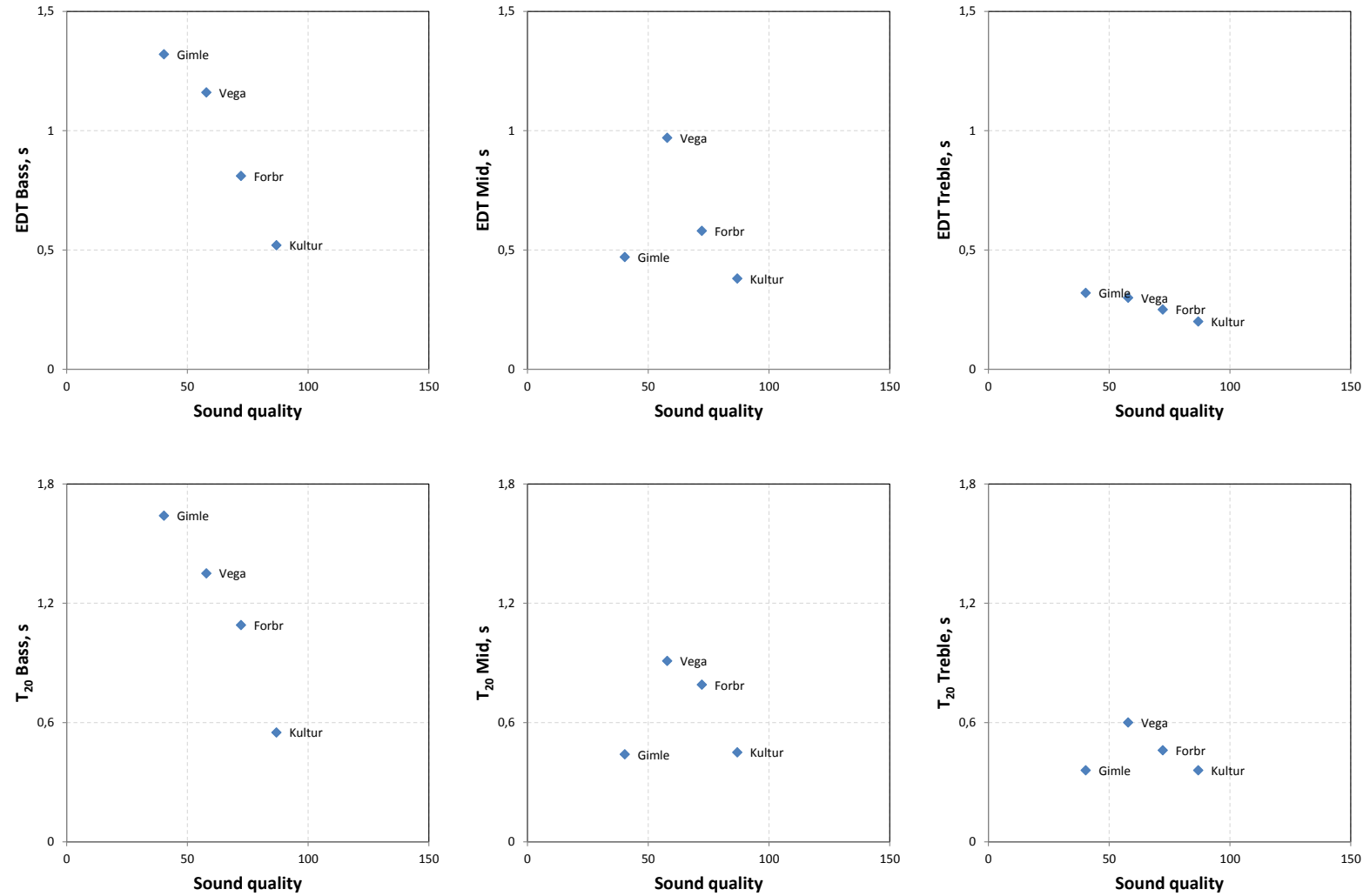


Figure 42

Plots showing the relations between the perceived Sound Quality and the perceptual attributes Clarity, Bass, Treble and Bass precision and the acoustic metrics relative bass and relative treble in dB.

**Figure 43**

Plots showing the relations between the perceived Sound Quality and the acoustic metrics early decay time, EDT for the bass, midrange and treble and the reverberation time T_{20} in the same frequency ranges.

It is seen that there are the same relations for EDT and T20 for each of the frequency ranges except for the treble T_{20} for Gimle.

8. Summary and Conclusions

8.1 Project overview

The purpose of the project was to establish knowledge as the background for sound quality specifications. The measurements aimed at establishing a connection between the physical measurements (acoustic measurements of metrics and characteristics for the sound system and venue), the perceived sound (perceptual domain – perceptual attributes assessed by experts) and the experienced sound (affective domain – audience preferences).

Eight different venues were used for the investigations:

- A large outdoor venue (Orange scene at Roskilde festival – max. 60.000 persons)
- Two tent venues (Cosmopol and Pavilion at Roskilde festival – max. 2-5000 persons)
- Five indoor venues (Gimle, Kulturstationen, Forbrændingen, Vega and Mantziusgården – max. 150-1550 persons)

The venues were equipped with sound systems from L-Acoustics, D&B and Meyer Sound.

The sound systems are regarded as consisting of two separate parts:

- The A-chain: The artistic chain, meaning the performers, the stage equipment and the mixing and effects made by a sound engineer with relations to the performer.
- The B-chain: The PA-system i.e. system signal processing, amplifiers and loudspeakers and the venue acoustics and for outdoor events including the influence of wind and weather on the sound propagation.

8.2 Acoustic measurements

The frequency characteristics of the sound systems (B-chain) were measured in at least 9 positions in the audience area for all venues. The results for the individual positions typically showed deviations from the mean response of ± 5 dB.

The general characteristics show a bass boost below approximately 100 Hz and a light a steady slope towards higher frequencies. One venue had a more flat characteristic.

The treble range drops in general with a steady slope to around minus 5 to minus 10dB (relative to the low midrange) at 16 kHz. It is assumed that this setting will avoid the sound to be perceived as sharp or uncomfortable at the relatively high sound pressure levels during concerts.

The frequency drop off was approximately below 40 Hz and above 12.5 kHz for all scenes. The deviations between the frequency characteristics of the venues are shown in Table 4.

1/3 octave frequency band	63 Hz	12.5 kHz
Deviation re. 1 kHz	+4 to +15 dB	-4 to -10 dB

Table 4

The deviations between the frequency characteristics (averaged over all positions for each venue) for two selected frequencies. For details see clause 6.1.1

Many room acoustic metrics was determined. It should be noted that the purpose of these measurements was to enlighten the perceived sound characteristics, so the measurements of these metrics was performed with the sound system as the sound source. This means that the directive sound systems will give a higher ratio between the direct and reverberant sounds field (just as the audience will perceive it) than if the measurements were performed with an omnidirectional sound source as normally used for room acoustic measurements.

1/3 octave frequency band	63 Hz	1kHz	4 kHz
EDT, indoor venues	0.4 - 1.4 s	0.3 – 1.1 s	0.3 – 0.8
EDT, tent venues	0.2 – 0.3 s	1.1 – 2.3 s	0.5 – 1.2

Table 5

The early decay times, EDT (averaged over all positions for each venue) for three selected frequencies. The sound systems were used as sound source for the measurements. For details see clause 6.1.2

A correlation analysis was performed between the room acoustic metrics (EDT, T_{10} , T_{20} , T_{30} , T_s , C_{80} , D_{50}) and as expected there were high correlations between some of them. EDT



, T_{20} and C_{80} was selected for presentation in the report. The results for EDT are summarized in Table 5. It is seen that the tent venues are characterized by short reverberation at the low frequencies and longer reverberation especially at the mid frequencies.

The sound pressure levels (L_{Aeq} , L_{AmaxF} , L_{Cpeak}) during the concerts was also measured. The main results are shown in Table 6.

Metric	L_{Aeq} , 15 min	L_{AmaxF}	L_{Cpeak}
Indoor venues	92 – 100 dB	104 – 109 dB	122 – 130 dB
Tent venues	92 – 102 dB	101 – 110 dB	125 – 134 dB

Table 6

The maximum sound pressure levels at the mixer position. The levels include concert sound and audience noise. For details see clause 6.1.3. The indoor venues had the same sound engineer and the tent venues are the results from 4 different concerts representing different music styles.

From the table it is seen that there are essential differences between the venues and that the maximum levels are slightly higher at the Roskilde festival than at the indoor venues.

8.3 Perceptual assessments

The following perceptual attributes were selected and defined:

- Overall Sound Quality (Lydkvalitet)
- Loudness (Lydstyrke)
- Clarity (Klarhed)
- Stability due to weather (Stabilitet) – not for the indoor venues
- Bass – the relative loudness of the bass (Bas)
- Treble – the relative loudness of the treble (Diskant)
- Bass precision (Bas præcision)
- Distortion (Forvrængning)
- Hum and hiss (Brum og susen)

These attributes were assessed by trained listeners during some of the concerts and for some of the indoor venues on binaural recordings reproduced over headphones with a subwoofer in DELTA's listening room

8.3.1 Assessments on the live concert locations

From the perceptual assessments on location with different live concerts the following results are found:

- The differences in the style of music and the settings of the A-chain may result in significant differences in the perceived sound characteristics for the same sound system assessed the same day. For details see Figure 30. It can be concluded that the A-chain has a very significant influence on the perception of the B-chain.

As the A-chain is central for the assessment of the B-chain, a trustworthy assessment of a B-chain requires a number of different A-chains. For Orange scene, Cosmopol and Pavilion two bands were assessed at each scene. Another possibility is to use the same A-chain for comparison of the B-chains. That was done for four of the indoor venues. For the on location assessments we found:

- Within the range of variation of the eight venues there are no significant differences in the assessments of the perceived sound characteristics when there are long periods (weeks, months years) between the assessments. For details see Figure 37. The only exception is the assessment of stability which was less for the only outdoor venue.

Despite the concerts having quite different acoustic characteristics and concert loudness measures, they were not rated significantly different. This could indicate that there is a range of acceptable variations at least of the magnitude as the variation in the data found in the previous mentioned acoustic measurements, and that it is difficult to accurately remember the acoustic properties of concerts even if it was a specific task for the assessors.

8.3.2 Assessments on reproduced live concerts

Assessments have also been made on binaural recordings of four of the live concerts reproduced over headphones with a subwoofer to give the physical sensation on the body of the lower bass. The assessments were made on the same songs with the same band and sound engineer for the four venues and as one of the live concert assessments.

A comparison between the live assessment and the assessment on the recording showed that the only significant differences in assessments were on the overall Sound Quality and the Clarity. Both the Sound Quality and Clarity were significantly higher in the live situation. There may be two reasons for that. One reason may be that you may perceive the sound more clearly with your own ears at the live event than through the ears of the Head And Torso Simulator used for the recordings. Another reason may be, that when you sit in a listening room with headphones your expectations may be more related to the higher clarity that you are used to from studio recordings or close microphone technique used in recordings from live concerts.

Contrary to the live concert assessments on location it is possible to make a direct comparison of the recordings from the different venues. This was done by using the SenseLabOnline listening test tool which made it possible to compare synchronised versions of the same songs. The results showed significant differences on most of the attributes for most of the four indoor venues. Furthermore there was a high correlation between the Attributes Sound Quality, Clarity and Treble.

The last finding seem to be in correspondence with some of the remarks from the live concerts at Roskilde 2012 where assessors also mention (see Appendix 12.4) that they had a very hard time understanding what the singer was actually singing (unable to determine the words, not related to language) and the many comments on the clarity and speech intelligibility.

8.4 Audience response

The audience response on the Sound Quality and the loudness of the music was collected at the live concerts for the indoor venues. Even if responses were obtained from 44-77 persons per venue no significant differences were found on these attributes in the collected data for the five venues. This is in accordance with the findings in the previous clause: If the assessors do not note a difference when they listen for it is not likely that the audience will give different responses for the different venues.

8.5 Relation between the physical and perceptual domains

As there were no differences in the audience response and the assessor evaluations at the on location assessments of the different venues it can be concluded that the variations found in the acoustic characteristics and the sound pressure levels for these venues are below the limit for noticeability under normal conditions. This also means that we can't use these data to find relations between the physical, perceptual and affective domain.

Based on the findings from the comparisons of the recordings of the indoor venues some relations between the physical and perceptual domain can be found. The most prominent relation was found between the perceived Sound Quality and the EDT of the bass. From the data it can be seen that EDT's at 0.5 sec. are preferred compared to higher values (up to 1,5 sec). The bass-EDT and the bass- T_{20} values for the venues are approximately the same. Whether even lower values would have been preferred cannot be seen from the data.

Low (0.2 sec.) values of the EDT for the treble also seem to be attractive but this may be a consequence of the high correlation between the treble-EDT's and the bass-EDT's.

There are some indications that a lower bass-level and a higher treble level will increase the Clarity and the Sound Quality.



8.6 General conclusions

Different methods of collected data for live concert venues and live concerts at these venues have been used for this project.

A number of relevant perceptual attributes are defined and compared to physical data for the venues.

Between the venues there were essential differences in the acoustic characteristics and the sound pressure levels during the concerts but these differences were below the Just Noticeable Differences (JND) when the assessments were made with time intervals larger than days (even when they were made by trained listeners with that specific task). This might also be seen as a tolerance of variations of a magnitude similar to the differences in the physical measurements found for the venues in this project.

In general the sound quality of the venues in this project was all above average and no poor venues were included. Therefore the lower limit for an acceptable sound quality could not be defined and therefore the results were less conclusive.

The project made it clear that large differences between venues are needed if there should be difference in assessments made with large time intervals. Comparison of binaural recordings from the venues will give a more detailed picture of the characteristics and a better resolution of the differences. So when a direct comparison (with the same band and sound engineer) is made the differences in the acoustic characteristics for the venues in this project are clearly audible. It should be remembered though, that we have seen that the influence of the band and the A-chain in general have an essential influence on the final result.

9. References

- [1] NORDTEST Method - NT ACOU 108
Acoustics: In situ measurements of permanently installed public address systems.
Approved 2001-06.
- [2] Rabie Khodr Jradi, s072470
Roskilde SoundRate App - System Specification
DTU, September 2012
- [3] Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)

10. Appendix - Assessment notebook for live perceptual evaluation



BEDØMMELSE AF LYDKVALITET COSMOPOL & PAVILLION 2012

Opgavebeskrivelse

Din opgave er at bedømme lydkvaliteten af den musik du hører. Det er udelukkende lydkvaliteten, der skal bedømmes, dvs. bedømmelsen skal så vidt muligt være uafhængig af hvilket band der spiller og uafhængig af om du synes musikken er god eller ej.

Høreværn

Du må selv bestemme om du vil bruge høreværn/ørepropper. Hvis du vælger at bruge høreværn skal det være den type der er udleveret til dig. Ørepropperne skal være i brug senest 15 minutter efter koncertens begyndelse og må tidligst tages ud når hele svarkemaet er udfyldt.

Sted og tid

Bedømmelsen skal foretages så tæt som muligt på den position du har fået tildelt, se side 2 og 3. Gå til din position i god tid før koncertens begyndelse.

Bedømmelsen skal foretages 30 minutter efter koncertens begyndelse.

Generelt om bedømmelserne

Sæt et kryds på svarakserne. Du må bruge hele akserne, – også den del der ligger udenfor ankerpunkterne.
Spørgsmål til Tore Stenborg-Andersen, Mobil: 23 66 83 23, e-mail: tos@delta.dk

01



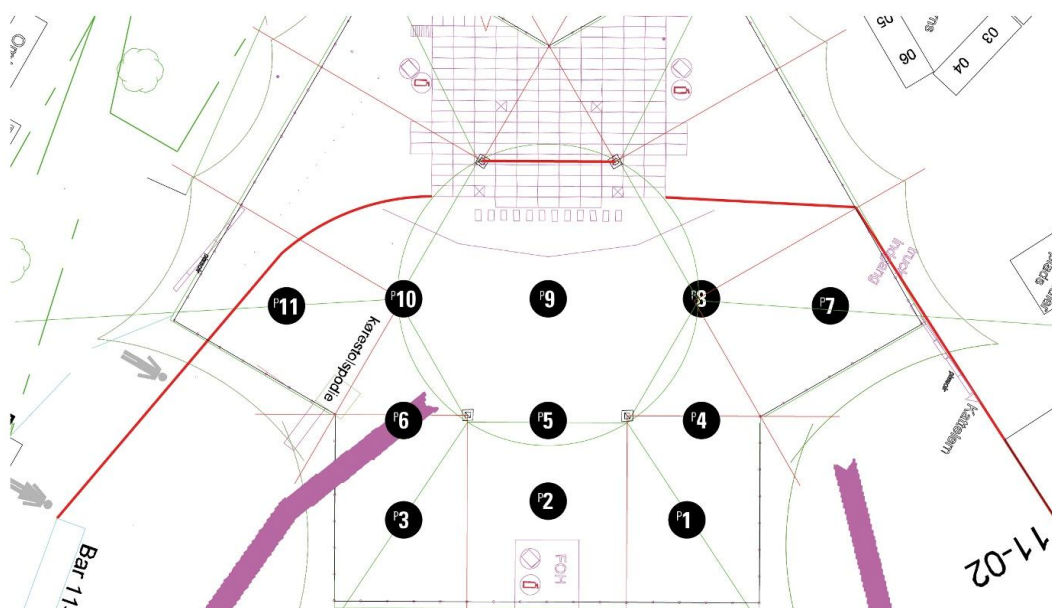
BEDØMMELSE AF LYDKVALITET COSMOPOL & PAVILLION 2012

Fordeling af målepositioner
Hver måleposition besættes med
følgende SenseLab-ekspertlyttere:

	TORS DAG		FREDAG	
	Cosmopol	Pavillion	Cosmopol	Pavillion
.....	P1	P3	P6	P9
.....	P2	P4	P7	P10
.....	P3	P5	P8	P11
.....	P4	P6	P9	P1
.....	P5	P7	P10	P2
.....	P6	P8	P11	P3
.....	P7	P9	P1	P4
.....	P8	P10	P2	P5
.....	P9	P11	P3	P6
.....	P10	P1	P4	P7
.....	P11	P2	P5	P8

02

BEDØMMELSE AF LYDKVALITET COSMOPOL 2012



BEDØMMELSE AF LYDKVALITET COSMOPOL 2012

Målepositioner

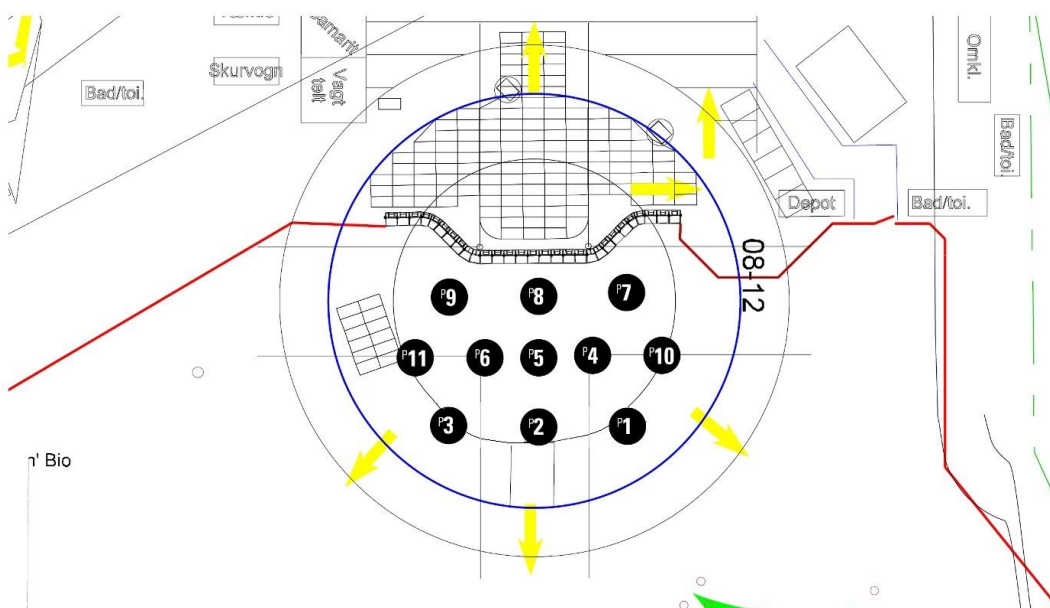
- P1** Hvor den forreste højre søjle flugter med højre højttaler, og så du står i samme afstand fra scenen som kanten af front of house. Dvs. ca. 4m fra teltekanten på din højre side.
- P2** Lige foran front of house, midt for.
- P3** Hvor forreste venstre søjle flugter med venstre højttaler, og du står i samme afstand fra scenen som kanten af front of house. Dvs. ca. 4m fra teltekanten på din venstre side.
- P4** Hvor forreste højre søjle flugter med højre højttaler, og i samme afstand fra scenen som de to bagerste søjler.
- P5** Midt imellem de to bagerste søjler.
- P6** Hvor forreste venstre søjle flugter med venstre højttaler, og i samme afstand fra scenen som de to bagerste søjler.
- P7** Hvor højre scenekant flugter med bagerste højre kant i teltet, samme afstand fra scenen som de to forreste søjler.
- P8** Lige ved indersiden af forreste højre søjle.
- P9** Midt imellem de to forreste søjler
Lige ved indersiden af forreste venstre søjle.
- P10** Hvor venstre scenekant flugter med bagerste venstre kant i teltet, samme afstand fra scenen som de to forreste søjler.

Generelt om bedømmelserne

Spørgsmål til Tore Stenborg-Andersen, Mobil: 23 66 83 23, e-mail: tos@delta.dk

04

BEDØMMELSE AF LYDKVALITET PAVILLION 2012



BEDØMMELSE AF LYDKVALITET PAVILLION 2012

Målepositioner

- | | |
|--|---|
| P1 Direkte bag højre søjle, samme afstand fra scenen som forreste kant af front of house. | P7 Direkte foran højre søjle, ca. 2-3m fra hegnet mod scenen. |
| P2 Midt foran front of house. | P8 Midt for, ca. 2-3m fra hegnet mod scenen. |
| P3 Direkte bag venstre søjle, samme afstand fra scenen som forreste kant af front of house. | P9 Direkte foran venstre søjle, ca. 2-3m fra hegnet mod scenen. |
| P4 Lige på indersiden af højre søjle. | P10 På højre kant af dansegulvet i samme afstand fra scenen som søjle. |
| P5 Midt imellem de to søjler. | P11 På venstre kant af dansegulvet i samme afstand fra scenen som søjle. |
| P6 Lige på indersiden af venstre søjle. | |

Generelt om bedømmelserne
Spørgsmål til Tore Stenborg-Andersen, Mobil: 23 66 83 23, e-mail: tos@delta.dk

06

BEDØMMELSE AF LYDKVALITET COSMOPOL & PAVILLION 2012

Navn: Måleposition:

Dato: Klokketæt:

Bruger du høreværn: ☐ Ja ☐ Nej

Scene: ☐ Cosmopol ☐ Pavillion

Bemærkninger, fx andre lydbeskrivende ord:

.....

.....

.....

.....

.....

Generelt om bedømmelserne
Spørgsmål til Tore Stenborg-Andersen, Mobil: 23 66 83 23, e-mail: tos@delta.dk

07



BEDØMMELSE AF LYDKVALITET

1. Lydkvalitet

Angiv din overordnede bedømmelse af lydkvaliteten:



2. Lydstyrke

Angiv hvad du synes om lydstyrken, dvs. hvor kraftig lyden er:



Generelt om bedømmelserne

Sæt et kryds på svarakserne. Du må bruge hele akserne, – også den del der ligger udenfor ankerpunkterne.
Spørgsmål til Tore Stenborg-Andersen, Mobil: 23 66 83 23, e-mail: tos@delta.dk

08

BEDØMMELSE AF LYDKVALITET

3. Klarhed

Er gengivelsen tydelig, klar og detaljeret uden tidsforsinkelser og/eller ekkoer?

Gengives instrumenter og vokaler præcist og distinkt?

Det modsatte af klarhed er: Sammenflydende, mudret, med ekkoer eller overdreven rumklang.



4. Stabilitet

Er lydengivelsen/lydkvaliteten stabil eller varierer lyden p.g.a vind og turbulenser?



Generelt om bedømmelserne

Sæt et kryds på svarakserne. Du må bruge hele akserne, – også den del der ligger udenfor ankerpunkterne.
Spørgsmål til Tore Stenborg-Andersen, Mobil: 23 66 83 23, e-mail: tos@delta.dk

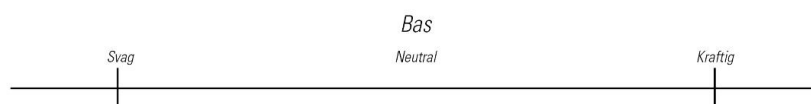
09

BEDØMMELSE AF LYDKVALITET COSMOPOL & PAVILLION 2012

5. Bas

Den relative styrke af bassen, dvs. de dybe toner (frekvenser) f.eks. mandestemmer, basguitar, stortrommer.

- En neutral bas placeres midt på svaraksen.



6. Diskant

Den relative styrke af diskanten, dvs. de lyse toner (høje frekvenser) fx. bækkener og s-lyde (hvislelyde).

- En neutral diskant placeres midt på svaraksen.



Generelt om bedømmelserne

Sæt et kryds på svarakserne. Du må bruge hele aksen, – også den del der ligger udenfor ankerpunkterne.
Spørgsmål til Tore Stenborg-Andersen, Mobil: 23 66 83 23, e-mail: tos@delta.dk

10

BEDØMMELSE AF LYDKVALITET COSMOPOL & PAVILLION 2012

7. Forvrængning

Er der mislyde som f.eks. hvislen, skratten eller forvrængning knyttet til musikken?

Er lyden klippet, uren, forvrænget, bliver s'-erne (hvislelyde) skarpe ved høj lydstyrke?

- Hvis ingen forvrængning er hørbar placeres svaret helt til venstre på svaraksen.



8. Brum og susen

Hvor meget brum og/eller susen høres fra højttalerne?

- Hvis ingen brum og/eller susen høres placeres svaret helt til venstre på svaraksen

- Hvis brum og/eller susen kun høres mellem numrene placeres svaret lavere end "Lidt".



Generelt om bedømmelserne

Sæt et kryds på svarakserne. Du må bruge hele aksen, – også den del der ligger udenfor ankerpunkterne.
Spørgsmål til Tore Stenborg-Andersen, Mobil: 23 66 83 23, e-mail: tos@delta.dk

11

11. Appendix – Questionnaire for audience opinion

DIN MENING OM LYDKVALITETEN?



DELTA SenseLab vil i samarbejde med
spillestedet gerne høre din mening

1. ANGIV HVOR I RUMMET DU HØRTE STØRSTEDELEN AF KONCERTEN

SCENE

DELTA SenseLab
Venlighedsvej 4
2970 Hørsholm
Denmark
Tel. +45 72 19 40 00
delta@delta.dk
senselab.madebydelta.com

VEND 



DIN MENING OM LYDKVALITETEN?

DELTA SenseLab vil i samarbejde med spillestedet gerne høre din mening



2. HVOR GODT SYNES DU OM STEDET OG SERVICEN?

A horizontal timeline with two vertical tick marks. The first tick mark is labeled "L1DT" and the second tick mark is labeled "MEGET".

3. HVOR GODT SYNES DU OM BANDET, SOLISTEN OG MUSIKKEN?

DÄRLIG FANTASTISK

4. HVOR GODT SYNES DU OM LYDKVALITETEN?

DÄRLIG FANTASTISK

5. HVAD SYNES DU OM LYDSTYRKEN?

[illegible]

AFLEVER VED UDGANGEN INDEN DU GÅR – TAK FOR DIN HJÆLP

25.112



12.2 Cosmopol

The general main layout for the measurement positions can be seen in Figure 11.

- P 1,1; P1,2; P1,3: 8,9m from stage front. P1,1 and P1,3 13m to each side of centre position.
- P2,1; P2,2; P2,3: 20,8m from stage front. P2,1 and P2,3 13m to each side of centre position.
- P3,1; P3,2; P3,3: 26,8m from stage front (5.3m from front of house). P3,1 and P3,3 13m to each side of centre position.
- P1,4 and P2,4: 14,4m from stage front. 7,2m on each side of centre position.

12.3 Pavillion

The general main layout for the measurement positions can be seen in Figure 11.

- P 1,1; P1,2; P1,3: 5,3m from main PA front. P1,1 and P1,3 7,9m to each side of centre position.
- P2,1; P2,2; P2,3: in line (left/right) with tent masts (9,6m from front of house). P2,1 and P2,3 7,9m to each side of centre position.
- P3,1; P3,2; P3,3: 0,9m from front of house. P3,1 and P3,3 7,9m to each side of centre position.
- P1,4 and P2,4: 3,3m towards stage front from each tent mast.

12.4 Comment analysis (Roskilde Festival 2012 only)

For Roskilde festival 2012 (the Cosmopol and Pavilion scenes) a systematic registration of the comments from the assessors were made.

Mentioned words	Number of assessors	Total comments	Negative	Positive	neutral	Ratio (neg/tot)
Muddy	5	8	7	0	1	0,88
Clarity	5	11	6	5	0	0,55
Speech Intelligibility	8	12	12	0	0	1,00
Bass	8	12	8	2	2	0,67
Treble	5	7	5	2	0	0,71
Ear Plugs	2	2	1	0	0	0,50
Position	4	5	0	0	5	0,00
Distortion	5	6	6	0	0	1,00
Echo/reverb	3	7	4	0	3	0,57

Table 7

Results from counting the number of occurrences of words related to different issues in the assessors comments made on the answering forms from the live concerts.

It is seen that many comments relate to the clearness (Clarity, muddy and speech intelligibility) of the sound. Tone balance (bass and treble) and the reverberation are next on the list, followed by the influence of the position and the perceived distortion.