Anders Christian Gade - DTU Orbit (26/10/2017)

Anders Christian Gade

Organisations

Associate Professor, Department of Acoustic Technology
04/07/2003 → 03/09/2013 Former
acg@elektro.dtu.dk
VIP

Associate Professor, Department of Electrical Engineering
04/07/2003 → 03/09/2013 Former
acg@elektro.dtu.dk
VIP

Publications:

Suitable reverberation time for halls for rock and pop music
The existing body of literature regarding the acoustic design of concert halls has focused almost exclusively on classical music, although there are many more performances of popular music, including rock and pop. Objective measurements were made of the acoustics of 20 rock music venues in Denmark and a questionnaire was used in a subjective assessment of those venues with professional rock musicians and sound engineers as expert listeners. Correlations between the measurements show that clarity, including bass frequencies down to 63 Hz, is important for the general impression of the acoustics of the hall. The best-rated halls in the study have reverberation times that are approximately frequency independent from 0.6 to 1.2 s for hall volumes from 1000 to 6000 m3. The worst rated halls in the study had significantly higher reverberation times in the 63 and 125 Hz bands. Since most audiences at rock concerts are standing, absorption coefficients were measured with a standing audience from 63 Hz to 4 kHz. These measurements showed that a standing audience absorbs about five times as much energy in mid-/high-frequency bands as in low-frequency bands.

General information
State: Published
Organisations: Hearing Systems, Department of Electrical Engineering
Authors: Adelman-Larsen, N. W. (Ekstern), Thompson, E. R. (Intern), Gade, A. C. (Intern)
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Scopus rating (2014): SJR 0.788 SNIP 1.423 CiteScore 1.8
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Teachers often suffer from health problems related to their voice. These problems are related to their working environment, including the acoustics of the lecture rooms. However, there is a lack of studies linking the room acoustic parameters to the voice produced by the speaker. In this pilot study, the main goals are to investigate whether objectively measurable parameters of the rooms can be related to an increase in the voice sound power produced by speakers and to the speakers' subjective judgments about the rooms. In six different rooms with different sizes, reverberation times, and other physical attributes, the sound power level produced by six speakers was measured. Objective room acoustic parameters were measured in the same rooms, including reverberation time and room gain, and questionnaires were handed out to people who had experience talking in the rooms. It is found that in different rooms significant changes in the sound power produced by the speaker can be found. It is also found that these changes mainly have to do with the size of...
the room and to the gain produced by the room. To describe this quality, a new room acoustic quantity called “room gain” is proposed.

**General information**

*State:* Published  
*Organisations:* Acoustic Technology, Department of Electrical Engineering, Acoustic Technology  
*Authors:* Brunskog, J. (Intern), Gade, A. C. (Intern), Bellester, G. P. (Ekstern), Calbo, L. R. (Ekstern)  
*Pages:* 2072-2082  
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Scopus rating (2012): SJR 0.763 SNIP 1.622 CiteScore 1.75  
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ISI indexed (2011): ISI indexed yes  
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BFI (2010): BFI-level 2  
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Web of Science (2010): Indexed yes  
BFI (2009): BFI-level 2  
Scopus rating (2009): SJR 0.783 SNIP 1.717  
Web of Science (2009): Indexed yes  
BFI (2008): BFI-level 2  
Scopus rating (2008): SJR 0.848 SNIP 1.633  
Web of Science (2008): Indexed yes  
Scopus rating (2007): SJR 0.865 SNIP 1.647  
Web of Science (2007): Indexed yes  
Scopus rating (2006): SJR 0.752 SNIP 1.559  
Web of Science (2006): Indexed yes  
Scopus rating (2005): SJR 0.954 SNIP 1.749  
Web of Science (2005): Indexed yes
Relationship between room shape and acoustics of rectangular concert halls

Extensive acoustics computer simulations have been made using Odeon computer simulation software. In 24 rectangular rooms representing "shoe-box" type concert halls with volumes of 8,000 m³, 12,000 m³ and 16,000 m³ from 300 to 850 measurements positions have been analysed. Only room averaged objective measures are considered here, in particular...
Clarity (C80), Strength (G) and Early Lateral Energy Fraction (LF80). Results from simulations have been compared with regression models created based on real hall measurements. In general, simulated results of C80 and G are found to be in good agreement with regression models. Divergences are found in LF80 behaviour; these have been associated with influence of proportions of rectangular halls. Updated formula for predicting of LF80 in rectangular halls has been proposed, which takes into the account both width and length of hall.

General information
State: Published
Organisations: Department of Acoustic Technology
Authors: Klosak, A. K. (Ekstern), Gade, A. C. (Intern)
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Main Research Area: Technical/natural sciences

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Web of Science (2014): Indexed yes
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Scopus rating (2008): SJR 0.848 SNIP 1.633
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Scopus rating (2006): SJR 0.752 SNIP 1.559
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Speaker comfort and increase of voice level in lecture rooms

Teachers often suffer health problems or tension related to their voice. These problems may be related to their working environment, including room acoustics of the lecture rooms which forces them to stress their voices. The present paper describes a first effort in finding relationships between the objectively measurable parameters of the rooms and the objective voice power produced by speakers. In rooms with different sizes, reverberation time and other physical attributes, the sound power levels produced by six speakers where measured while giving a short lecture. Relevant room acoustic parameters were also measured in the rooms and subjective impressions from about 20 persons who had experience talking in these rooms were collected as well. Analysis of the data revealed significant differences in the sound power produced by the speaker in the different rooms. It was also found that these changes were mainly related to the size of the room and to the gain or support produced by the room. To describe this quality, a new room acoustic quantity called 'room gain' is proposed.
The importance of bass clarity in pop, rock and multi purpose venues

**General information**
State: Published
Organisations: Acoustic Technology, Department of Electrical Engineering, Flex Acoustics
Authors: Larsen, N. W. (Ekstern), Gade, A. C. (Intern), Thompson, E. R. (Intern)
Publication date: 2008
Main Research Area: Technical/natural sciences
Source: orbit
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Publication: Research › Poster – Annual report year: 2008

**Trends in preference, programming and design of concert halls for symphonic music**
This paper discusses the evolution in taste regarding concert hall acoustics and how this can be reflected in the new halls being built today. The clients’ and listener's preferences are not only based on listening in existing halls; but also on listening to reproduced music recorded with microphones close to the orchestra and with artificial reverberation added. The result may be a desire for higher clarity as well as a more full reverberation than what is found in most existing halls. Without being very specific in the brief regarding geometrical detailing - which is not desirable as it will limit architectural freedom and evolution - we can only specify a desire for acoustic conditions in this direction by setting targets for standardized objective room acoustic parameters. In this paper, measured ISO 3382 data are used to illustrate typical differences between "live" and recorded concert experiences, and it is seen how visionary hall designs over the last four decades tend to move the acoustics of halls in the same direction. Finally, it is suggested how target values for ISO 3382 parameters - in spite of their limitations - can be set up to drive the design in such a direction.

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Organisations: Department of Electrical Engineering
Authors: Gade, A. C. (Intern)
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ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
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ISI indexed (2012): ISI indexed yes
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Acoustic investigations of concert halls for rock music

Objective measurement data and subjective evaluations have been collected from 20 small-/medium-sized halls in Denmark used for amplified rhythmic music concerts (pop, rock, jazz). The purpose of the study was to obtain knowledge about optimum acoustic conditions for this type of hall. The study is motivated by the fact that most concert tickets sold in Denmark relate to concerts within these genres in this kind of venue. The subjective evaluations were carried out by professional musicians and sound engineers who responded on the basis of their experiences working in these (and other) halls. From the relationships between the subjective evaluations and the objective data, recommended values for reverberation time across frequency are suggested. For halls with volume between 50,000 ft³ and 160,000 ft³, the optimal range is 0.7 s to 1.0 s without audience (and chairs). T₃₀ should be frequency independent, so that clarity remains high also at the lower frequencies. A lower limit for T₃₀ was identified. The paper also proposes possible hall designs that seek to fulfill the demands of sound engineers and musicians, as found in the investigation.
Acoustics in rock and pop music halls

The existing body of literature regarding the acoustic design of concert halls has focused almost exclusively on classical music, although there are many more performances of rhythmic music, including rock and pop. Objective measurements were made of the acoustics of twenty rock music venues in Denmark and a questionnaire was used in a subjective assessment of those venues with professional rock musicians and sound engineers. Correlations between the objective and subjective results lead, among others, to a recommendation for reverberation time as a function of hall volume. Since the bass frequency sounds are typically highly amplified, they play an important role in the subjective ratings and the 63-Hz-band must be included in objective measurements and recommendations.

General information
State: Published
Organisations: Acoustic Technology, Department of Electrical Engineering, Flex Acoustics
Authors: Adelman-Larsen, N. W. (Ekstern), Thompson, E. R. (Intern), Gade, A. C. (Intern)
Publication date: 2007
The Flexible Bass Absorber
Multi-purpose concert halls face a dilemma. They host different performance types that require significantly different acoustic conditions in order to provide the best sound quality to both the performers, sound engineers and the audience. Pop and rock music often contain high levels of bass sound energy but still require high definition for good sound quality. The mid- and high-frequency absorption is easily regulated, but adjusting the low-frequency absorption has typically been too expensive or requires too much space to be practical for multi-purpose halls. A practical solution to this dilemma has been developed. Measurements were made on a variable and mobile low-frequency absorber. The paper presents the results of prototype sound absorption measurements as well as elements of the design.

General information
State: Published
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Authors: Adelman-Larsen, N. W. (Ekstern), Thompson, E. R. (Intern), Gade, A. C. (Intern)
Pages: S58
Publication date: 2007

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Publication: Research › Article in proceedings – Annual report year: 2007

Acoustical computer simulations of the ancient Roman theatres

General information
State: Published
Organisations: Acoustic Technology, Department of Electrical Engineering
Authors: Nielsen, M. L. (Ekstern), Rindel, J. H. (Intern), Gade, A. C. (Intern), Christensen, C. L. (Intern)
Pages: 20-26
Publication date: 2006

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Acoustics of ancient Greek and Roman theaters in use today

In the Mediterranean area a large number of open, ancient Greek and Roman theatres are still today facing a busy schedule of performances including both classical and contemporary works of dance, drama, concerts, and opera. During the EU funded "Erato" project and a subsequent master thesis project, extensive measurement data have been collected from three well-preserved theatres, which represent three different stages of enclosing the audience in an open-air environment: (1) the Epidaurus Theatre in Greece without skenae wall or columnade behind the cavea; (2) the Jerash South theatre in Jordan with skenae wall but no columnade; and (3) the Aspendos Theatre in Turkey having both a full skenae building and a columnade around the cavea. In the paper the acoustic characteristics of these theatres will be compared and discussed in the light of acoustic performance requirements for modern use.
Is reverberation time adequate for testing the acoustical quality of unroofed auditoriums?

Especially during summertime, public squares, stadiums and other kinds of open spaces, are frequently used for live concerts (pop, jazz, classical, etc.) - both with and without amplification. Based on the first author's PhD thesis, this paper aims at illustrating whether reverberation time (EDT, $T_{30}$) and other acoustical parameters normally used to test the acoustical quality of closed auditoria, such as concert halls, theatres, opera houses, are suitable and sufficient for testing the acoustical quality of open performance spaces. Simulations as well as measurements were carried out to study the acoustics of open squares surrounded by hard, vertical, reflecting building facades. Especially when concerts are amplified, echoes or flutter echoes are often found to be the most important characteristic – and problem! Therefore, emphasis was given to finding an acoustical parameter – or a set of parameters - which could illuminate this problem. The results indicated that the value of Centre Time ($T_s$), compared with its expected value based on Reverberation Time, has a potential for echo detection, but also Speech Transmission Index, (STI), Strength ($G$), and Clarity ($C_{80}$) - and when computer simulations are carried out – auralisations, are valuable for “Agora acoustics” investigations.
The virtual reconstruction of the ancient Roman concert hall in Aphrodisias, Turkey
About two thousand years ago one of the world's earliest and most beautiful concert halls were built in the city
Aphrodisias, named after the goddess Aphrodite. It was a rich society, renowned for its marble and mastery in sculptures.
Like many other cities in the Roman Empire there was an open-air theatre for plays and a roofed theatre, Odeon, for
certons. In the framework of an EU-project the Odeon or concert hall has been reconstructed in a virtual environment,
visually and acoustically. The capacity of the hall was around 1000 in the audience. There has been some uncertainty
about the original height of the ceiling; but with the suggested reconstruction the reverberation time with a full audience is
around 1.6 s at mid frequencies. The influence on the acoustics of various architectural elements has also been studied.
The virtual reconstruction, including some auralization examples with reconstructed music, has been made with the
ODEON room acoustic modelling program. From January 2006 the reconstructed concert hall will be open for visitors,
although in a virtual environment. The address is: http://www.at.oersted.dtu.dk/~erato.

General information
State: Published
Organisations: Department of Electrical Engineering, Acoustic Technology
Authors: Rindel, J. H. (Intern), Gade, A. C. (Intern), Nielsen, M. L. (Ekstern)
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Agorá Acoustics - Effects of arcades on the acoustics of public squares
This paper is part of a PhD work, dealing with the acoustics of the public squares ('Agorá Acoustics'), especially when
music (amplified or not) is played. Consequently, our approach will be to evaluate public squares using the same set of
acoustics concepts for subjective evaluation and objective measurements as applied for concert halls and theatres. In this
paper the acoustical effects of arcades will be studied, in terms of reverberation (EDT and T30), clarity (C80), intelligibility
(STI) and other acoustical parameters. For this purpose, also the theory of coupled rooms is applied and compared with
results. An acoustic modelling program, ODEON 7.0, was used for this investigation. Three different sizes of public
squares were considered. In order to evaluate the 'real' effects of the arcades on the open square, models of all three
squares were designed both with and without arcades. The sound source and the receivers were positioned in the open
square as well as in the arcades (making four different combinations). The results show that, when adding arcades to an
open square, an increase in reverberation time is observed: a criterion is studied to predict in which cases arcades have
this effect. Arcades can also cause a decrease in Clarity (C80), Strength (G) and STI in the main open area. Arcades
cannot be considered responsible for double decay in the open area; however the open square can cause a double decay
under the arcades, if both sound source and receiver are positioned in the same arcade. Finally, the distribution of energy
through the coupling surface is discussed using Statistical Energy Analysis (SEA).

General information
State: Published
Organisations: Acoustic Technology, Department of Electrical Engineering
Authors: Paini, D. (Ekstern), Gade, A. C. (Intern), Rindel, J. H. (Intern)
Publication date: 2005
A variable passive low-frequency absorber

Multi-purpose concert halls face a dilemma. They can host classical music concerts, rock concerts and spoken word performances in a matter of a short period. These different performance types require significantly different acoustic conditions in order to provide the best sound quality to both the performers and the audience. A recommended reverberation time for classical music may be in the range of 1.5–2 s for empty halls, where rock music sounds best with a reverberation time around 0.8-1 s. Modern rhythmic music often contains high levels of sound energy in the low frequency bands but still requires a high definition for good sound quality. Ideally, the absorption of the hall should be adjustable in all frequency bands in order to provide good sound quality for all types of performances. The mid and high frequency absorption is easily regulated, but adjusting the low-frequency absorption has typically been too expensive or requires too much space to be practical for multi-purpose halls. Measurements were made on a variable low-frequency absorber to develop a practical solution to the dilemma. The paper will present the results of the measurements as well as a possible design.

General information
State: Published
Organisations: Department of Electrical Engineering, Acoustic Technology
Authors: Larsen, N. W. (Ekstern), Thompson, E. R. (Intern), Gade, A. (Intern)
Publication date: 2005

How did the ancient Roman Theatres sound?

The Roman theatre follows a natural evolution from the Greek theatre combining the acting area and the seating area into a single structure. Modifications of stage, orchestra and seating area have resulted in a considerable improvement in the quality of the acoustics. As a part of the ERATO project, the acoustics in Roman theatres and Odea (roofed theatres) have been recreated through computer simulations using the Odeon software. Computer models of five Roman theatres have been created based on data from archaeologists, architects and measurements in situ. The theatres have been modelled in their present state and as they presumably were built in the Roman era; the reconstructed parts of acoustical interest are the stage wall and top colonnade in the open-air theatres and the roof and windows in the Odea. The irregular absorption distribution in these rooms makes them challenging for acoustical simulations differing from traditional concert halls. Auralisation examples will be presented using fragments of Roman music recorded in the project.

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Organisations: Acoustic Technology, Department of Electrical Engineering
Authors: Nielsen, M. L. (Intern), Rindel, J. H. (Intern), Gade, A. C. (Intern), Christensen, C. L. (Intern)
Publication date: 2005
Matching simulations with measured acoustic data from Roman Theatres using the ODEON programme
In the context of the ERATO research project ("identification, Evaluation and Revival of the Acoustical heritage of ancient Theatres and Odea") funded by the European Union, acoustic measurements as well as computer simulations have been carried out in the Aspendos Theatre, Turkey and in the south theatre in Jerash, Jordan. The simulations are made with the ODEON software, for which a new frequency-dependent diffraction method is currently being developed for implementation in future versions of the programme. In order to make the virtual restorations of these ancient Roman theatres as correct as possible, it is important to attempt calibration of the models with respect to as many of the relevant acoustic parameters as possible. Thus, besides the overall value of reverberation time, we also try to match the variation with position of other important acoustic parameters, such as Strength and Clarity described in ISO 3382. With the new diffraction and scattering calculation method we hope to improve this match, because these phenomena are regarded very important for the acoustics in these open air theatres, in which the sound field is far from being a “normal” three-dimensional diffuse field. The paper describes this exercise, the calculation parameters in ODEON that were adjusted in the process, and the extent to which it was successful.

Acoustics in halls for rock music

Roman Theatres; Comparison of acoustic measurements and simulation results from Aspendos Theatre, Turkey.
Room acoustic measurements have been carried out in the best preserved of all Roman theatres, the Aspendos Theatre in Turkey. The results are compared with simulated values from a rough as well as a very detailed ODEON model of the theatre.
The acoustics of public squares/places: A comparison between results from a computer simulation program and measurements in situ

In the contest of a PhD thesis, in which the main purpose is to analyse the importance of the public square/place ("agora") as a meeting point of sound and music, with particular regard to its use for concerts (amplified or not), a first step was done, making comparisons between measurement in situ and results coming from a computer simulation program (Odeon), usually used for enclosed places, such as theatres, concert halls, etc. The main objective of this paper is to study how accurate such a program is in a contest (a public place) which could have a regular or a complex shape, and which is not completely closed and not completely open, with highly reflecting and partially diffusing vertical surfaces (the facades) and with one totally absorbing surface (the sky). A natural application of these results will be the possibility to detect the best position for a sound source (typically an orchestra or a band during, for instance, music summer festivals) and the best position for the audience. A further result could be to propose some acoustic adjustments to achieve better acoustic quality by considering the acoustic parameters which are typically used for concert halls and opera houses.

General information
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Organisations: Department of Electrical Engineering
Authors: Paini, D. (Ekstern), Rindel, J. H. (Intern), Gade, A. (Intern), Turchini, G. (Ekstern)
Publication date: 2004

The role of acoustics in the planning of performance halls in Copenhagen

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Organisations: Department of Electrical Engineering
Authors: Gade, A. (Intern)
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Acoustic renovation of two Danish Theatres

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Organisations: Department of Electrical Engineering
Authors: Gade, A. (Intern)
Publication date: 2002
Den arbejdende hjerne - hvordan kan den se ud?

General information
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Organisations: Department of Electrical Engineering, Cognitive Systems, Department of Informatics and Mathematical Modeling
Authors: Paulson, O. B. (Ekstern), Born, P. (Ekstern), Bundesen, C. (Ekstern), Gade, A. (Intern), Gerlach, C. (Ekstern), Hansen, L. K. (Intern), Holm, S. (Ekstern), Jensen, M. (Ekstern), Kyllingsbæk, S. (Ekstern), Larsen, A. (Ekstern), Law, I. (Ekstern), Rostrup, E. (Ekstern), Svarer, C. (Ekstern)
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- BFI (2015): BFI-level 1
- Scopus rating (2015): SJR 0.124 SNIP 0.077 CiteScore 0.03
- BFI (2014): BFI-level 1
- Scopus rating (2014): SJR 0.129 SNIP 0.116 CiteScore 0.05
- BFI (2013): BFI-level 1
- Scopus rating (2013): SJR 0.14 SNIP 0.122 CiteScore 0.06
- ISI indexed (2013): ISI indexed no
- BFI (2012): BFI-level 1
- Scopus rating (2012): SJR 0.146 SNIP 0.15 CiteScore 0.08
- ISI indexed (2012): ISI indexed no
- BFI (2011): BFI-level 1
- Scopus rating (2011): SJR 0.143 SNIP 0.157 CiteScore 0.1
- ISI indexed (2011): ISI indexed no
- BFI (2010): BFI-level 1
- Scopus rating (2010): SJR 0.158 SNIP 0.169
- Web of Science (2010): Indexed yes
- BFI (2009): BFI-level 1
- Scopus rating (2009): SJR 0.156 SNIP 0.201
- BFI (2008): BFI-level 1
- Scopus rating (2008): SJR 0.155 SNIP 0.17
- Web of Science (2008): Indexed yes
- Scopus rating (2007): SJR 0.147 SNIP 0.157
- Web of Science (2007): Indexed yes
- Scopus rating (2006): SJR 0.139 SNIP 0.163
- Web of Science (2006): Indexed yes
- Scopus rating (2005): SJR 0.142 SNIP 0.173
- Scopus rating (2004): SJR 0.172 SNIP 0.209
The acoustical history of Hagia Sophia revived through computer simulations

The present paper deals with acoustic computer simulations of Hagia Sophia, which is characterized not only by being one of the largest worship buildings in the world, but also by – in its 1500 year history – having served three purposes: as a church, as a mosque and today as a museum. The investigation is done as a part of the EU project - CAHRISMA.

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Authors: Rindel, J. H. (Intern), Weitze, C. (Ekstern), Christensen, C. L. (Intern), Gade, A. (Intern)
Publication date: 2002

Host publication information
Title of host publication: Proceedings of Forum Acusticum
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 187968
Publication: Research - peer-review › Article in proceedings – Annual report year: 2002

Acoustical problems in orchestra pits: causes and possible solutions

General information
State: Published
Organisations: Department of Electrical Engineering
Authors: Gade, A. (Intern), Kapenekas, J. (Ekstern), Andersson, B. (Ekstern), Gustafsson, J. (Ekstern)
Publication date: 2001

Host publication information
Title of host publication: Proceedings of 17th International Congress on Acoustics, Rome, Italy, 2-7 September
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 60401
Publication: Research - peer-review › Article in proceedings – Annual report year: 2001

Acoustic concerns related to multi cultural societies

Immigration has increased cultural diversity in western societies. The process of integrating immigrants into their host countries can be smoothed if acousticians learn to recognize (1) the acoustic traditions of immigrant cultures and (2) the specific acoustic needs of the new society members. Two related projects are discussed. The "Cahrisma" project (Conservation of Acoustical Heritage by the Revival and Identification of the Sinan's Mosque Acoustics) is sponsored by the European Commission and carried out in cooperation among researchers in Turkey, Malta, Italy, France, Switzerland, and Denmark. Its purpose is to combine visual and acoustical concerns in the identification, conservation, and restoration of architectural heritage. It focuses on the famous Turkish mosques of the Osmannic architect Sinan. Some of the acoustic features of these large domed buildings and of muslim liturgy will be presented. Another project was conducted by students at the Danish Technical University, who found that speech intelligibility for non-native listeners is much more sensitive to poor speech conditions than for native listeners. Also discussed are the unique features of culturally based urban soundscapes. It is suggested that these soundscapes can provide comfort to recent immigrants by increasing their sense of being "at home."
Early reflection energy in concert halls: how much, how early, and from where (A)

Today, the importance of distributing early reflection energy to listeners and performers in concert halls is well understood and accepted—also among architects. Still, implementation in the practical design of a large hall is not easy, partly because we still have difficulties quantifying precisely the demands in detail (how much, how early, and from where) due to limitations in our acoustic knowledge—and often also due to little response from the clients regarding their preferences when decisions between alternative demands must be made. Therefore, in general it is up to the acoustician to decide how far to promote the good cause on the basis of his/her experience, taste, and talent in influencing the decision process.
The aural presentation will focus on the current limitations in our knowledge regarding the musicians' need for early reflections, which is a special challenge in the design of terraced, "surround" concert halls. In the case of the listeners, knowledge has reached a much higher level, and recent results regarding how room shape influence the objective acoustic parameters monitoring the early energy will be presented.
Validation of an auralization system

The room acoustics program odeon provides auralization using fully filtered binaural room impulse responses, each reflection being filtered through nine octave bands and a set of head-related transfer functions. Using the full filtering scheme allows, in principle, a complete audible presentation of all the properties, time-variant frequency coloration, as well as directional information predicted by the room acoustics program. Two methods of verification have been applied. The first method is based on direct measurements on the impulse responses predicted by odeon, using the room acoustics measuring system dirac in order to verify that the auralization method is actually capable of reproducing the predicted room acoustic parameters. Monaural auralization filters were used for this purpose. The other method is an audible comparison between in situ recordings of a singing person in real rooms and the odeon auralization of the same situations. The latter verification is part of an ongoing European research project, CAHRISMA, on restoration of the acoustics in old Byzantine churches and mosques in Istanbul.
Several objective measures have been proposed to describe the feeling of spatial impression in concert halls, including Lateral Energy Fraction (LF) and Interaural Cross-Correlation Coefficient (IACC). However, previous studies have shown that LF and IACC values did not highly correlate with each other at individual seat positions in real halls [J. S. Bradley, J.
To investigate the listener envelopment aspect of spatial impression further, subjective paired-comparison tests have been run using signals which have various values for LF, early IACC (from 5–80 ms), late IACC (from 80 ms–1 s), and late lateral relative sound level (GLL). Another proposed measure, called Interaural Level Fluctuations (IALF), has also been included, which is based on the rate of change over time of the level difference between the ears. The binaural test signals were generated by the room acoustics simulation program ODEON, using four different musical motifs, and were presented to test subjects via headphones. Results from the experiments are presented. [Work supported by ASA Hunt Postdoctoral Research Fellowship.]
Scopus rating (2006): SJR 0.752 SNIP 1.559
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.954 SNIP 1.749
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.77 SNIP 1.787
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.882 SNIP 1.712
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.87 SNIP 1.501
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.719 SNIP 1.467
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.621 SNIP 1.411
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Scopus rating (1999): SJR 0.591 SNIP 1.319

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Publication: Research - peer-review » Journal article – Annual report year: 2000

Can reverberation enhancement systems change perception of other room acoustic aspects than just reverberation?

General information
State: Published
Organisations: Department of Acoustic Technology
Authors: Gade, A. C. (Intern), Mortensen, F. R. (Intern)
Publication date: 1999

Host publication information
Title of host publication: Can reverberation enhancement systems change perception of other room acoustic aspects than just reverberation?
Main Research Area: Technical/natural sciences
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Publication: Research - peer-review » Book chapter – Annual report year: 1999

Comparisons between computer simulations of room acoustical parameters and those measured in concert halls
A number of European concert halls were surveyed in 1989. In this paper comparisons are made between measured room acoustical parameters and those obtained from computer simulations on concert halls using the odeon program version 3.1. The key parameter compared with measured data is the reverberation time, and this is mainly used to adjust the absorption data of the surfaces in the computer model. But five additional parameters are calculated and compared with measured data as well. In order to determine the sensitivity of the computer model, comparisons are also made between the results obtained from computer simulations using models with a high geometrical fidelity and those from models with simplifications to geometry that are in better agreement with the laws of high-frequency modeling.

General information
State: Published
Organisations: Department of Acoustic Technology, Department of Electrical Engineering
Authors: Rindel, J. H. (Intern), Shiokawa, H. (Ekstern), Christensen, C. L. (Intern), Gade, A. C. (Intern)
Pages: 1173-1173
Publication date: 1999
Main Research Area: Technical/natural sciences
Comparisons between Computer Simulations of Room Acoustical Parameters and those Measured in Concert Halls

Recent multi-purpose hall designs in Denmark with physically variable acoustics

This paper describes two recent Danish multi-purpose hall designs, in which acoustic variability has been accomplished in different ways: through variable absorption and variable volume, respectively. The different approaches were chosen in order to insure that not only reverberation time (T) and so clarity (C), but also the strength parameter (G) could be varied in a favorable direction in view of the prescribed uses of the halls. The hall with variable absorption is the assembly hall in the new extension to the Royal Library in Copenhagen to open in fall 1999. This hall will seat 600 people and be used for chamber music concerts, symphony orchestra rehearsals, and amplified speech. For the latter two functions, a reduction in G along with reduction in T was considered favorable. The hall with variable volume is the recently opened Esbjerg Musikhus seating 1100 and equipped with a full stage house. This hall is used for symphonic concerts and musicals as well as drama and conferences. In this hall, maintaining or even increasing G along with a reduction in T is advantageous, especially in the drama theatre mode. The paper will describe the design of these two halls along with acoustic measurement results.
Compromises in orchestra pit design: A ten-year trench war in The Royal Theatre, Copenhagen

The "old stage" of The Royal Theatre in Copenhagen—a classical horseshoe theatre with an almost flat audience floor and four balcony levels—is the primary opera and ballet theatre in Denmark. In the early 1980s the orchestra pit was enlarged and its size made flexible. However, in the following years this new flexibility caused a formal battle between the orchestra, the singers, and management, because each group had different interests as to how the pit should be configured for each new production. In the 1990s, increased concern about the musicians' hearing and the increase in the popularity of opera finally opened the way for a new renovation of the pit, which solved most of the problems. The paper describes the many lessons learned during the ten-year period in which the authors were involved with the case as acoustic consultants. Questions of how pit configuration influences mutual hearing and exposure levels in the pit, balance between singers and orchestra as judged by the audience, communication between stage and pit, as well as the influence of pit floor construction on orchestra timbre will all be illustrated by results of numerous objective measurements, subjective surveys, and computer simulations.

General information
State: Published
Organisations: Department of Acoustic Technology, Royal Danish Academy of Fine Arts
Authors: Gade, A. C. (Intern), Mortensen, B. (Ekstern)
Pages: 2786-2786
Publication date: 1998
Main Research Area: Technical/natural sciences

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Volume: 103
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Ratings:
BFI (2018): BFI-level 2
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.83 SJR 0.749 SNIP 1.27
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.802 SNIP 1.437 CiteScore 1.77
Web of Science (2015): Indexed yes
Simultaneous measurements of room-acoustic parameters using different measuring equipment?

Often the results from different room-acoustic measurements in the same hall disagree, and the disagreement is just said to be due to different measuring equipment, or different rigging/temperature, etc. The room acoustic of the Oslo Concert Hall was measured simultaneously, using the following different measuring equipment: (1) MLS/MLSSA (Statsbygg), (2) Sweep-Tone (Tech. Univ. Denmark), and (3) Norsonic 840 with MLS+MatLab. For some of the measurements (4) Pistol and (5) Electrical Impulse were also used. The paper will compare the results from the different measuring equipment, for the most known room-acoustic parameters. For the reverberation time parameters RT and EDT, very good agreement was found between the three main measuring equipments. For Ts and C80 the agreement between these three is good/fair for the higher frequencies, but less good for the bass, especially C80. The measurements with Electric Pulse and Pistol as signals (analyzed through Norsonic+MatLab) indicate good agreement for the reverberation times, but EDT is somewhat higher for the Pistol. For Ts and C80 the Electric Impulse and especially the Pistol give less clearness (higher Ts and lower C80), compared to MLSSA, Sweep Tone, and Norsonic/MLS.
Evaluation of a reverberation enhancement system installed in a small multi purpose hall

After design and installation of a reverberation enhancement system in new 400 seat multi purpose hall in Vejle, Denmark, room acoustic measurements and listening tests were performed in order to reveal the objective and subjective performance and limits of such a powerful tool for altering "room acoustic" properties. The compromises in realistic choice of acoustic parameters for the different settings of the system are described with reference to the natural acoustics and functional needs of the hall in question. Although the enhancement system is capable of increasing the reverberation time by a factor of three, it is found that an increase of about 50% (from 1.1 to 1.7 sec.) is about the limit beyond which critical listeners start complaining about lack of realism. Possible reasons for this are discussed.

General information
State: Published
Organisations: Department of Acoustic Technology
Authors: Gade, A. C. (Intern)
Pages: 522-529
Publication date: 1997
Main Research Area: Technical/natural sciences

Publication information
Journal: Acustica
Volume: 83
Issue number: 3
ISSN (Print): 0001-7884
Ratings:
The influence of basic design variables on the acoustics of concert halls; new results derived from analysing a large number of existing halls

General information
State: Published
Organisations: Department of Acoustic Technology
Authors: Gade, A. C. (Intern)
Pages: 96-102
Publication date: 1997

Host publication information
Title of host publication: Proceedings of the Institute of Acoustics
Place of publication: St Albans
Publisher: Institute of Acoustics
Main Research Area: Technical/natural sciences
Conference: Institute of Acoustics Meeting, Belfast, 01/01/1997
Source: orbit
Source-ID: 167734
Publication: Research - peer-review › Article in proceedings – Annual report year: 1997

Loudspeaker systems in rooms

General information
State: Published
Organisations: Department of Acoustic Technology
Authors: Gade, A. C. (Intern)
Number of pages: 79
Publication date: 1996

Publication information
Original language: Danish
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 166344
Publication: Research - peer-review › Book – Annual report year: 1996

Room acoustic enhancement in a small hall with very low natural reverberation time

General information
State: Published
Organisations: Department of Acoustic Technology
Authors: Gade, A. C. (Intern)
Pages: 516-516
Publication date: 1996

Host publication information
Title of host publication: NAM 96 - Proceedings
Place of publication: Helsinki
Publisher: The Acoustical Society of Finland
Main Research Area: Technical/natural sciences
Room acoustic properties of concert halls: Quantifying the influence of size, shape, and absorption area

A large database of values of various room acoustic parameters has provided the basis for statistical analyses of how and how much the acoustic properties of concert halls are influenced by their size, shape, and absorption area (as deduced from measured reverberation time). The data have been collected over a 15-year period from about fifty concert halls in Europe and the U.S.A. In all halls the same measurement technique was used (1/1 octave sweep tones all bandpass filtered to form impulse responses per octave band). Because of the large range of geometric differences contained in the material, it has been possible to derive empirical regression formulas from which the influence of certain geometrical design variables can be quantified. The author has found these fairly simple relationships useful in teaching and as guidelines both in the early stages of physical hall design and in setting up electronic reverberation enhancement systems.
Simultaneous measurements of room acoustic parameters using different measuring equipment

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Acoustical measurements on stages of nine U.S. concert halls
A measurement tour of nine U.S. concert halls included acoustical measurements on the stage of each hall. Two teams (from the National Research Council of Canada, and the Technical University of Denmark) made measurements of the acoustical quantities suggested by Gade: the “support” family of measures describing the acoustical conditions for the musicians on stage. This paper compares the results from the two measurement teams and discusses the influence of hall...
General information
State: Published
Organisations: Department of Electrical Engineering
Authors: Gade, A. C. (Intern), Bradley, J. S. (Ekstern)
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Publication date: 1993
Main Research Area: Technical/natural sciences

Publication information
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BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.83 SJR 0.749 SNIP 1.27
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Scopus rating (2015): SJR 0.802 SNIP 1.437 CiteScore 1.77
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 0.788 SNIP 1.423 CiteScore 1.8
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 0.705 SNIP 1.966 CiteScore 2
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.763 SNIP 1.622 CiteScore 1.75
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.695 SNIP 1.642 CiteScore 1.68
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 0.754 SNIP 1.528
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 0.783 SNIP 1.717
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 0.848 SNIP 1.633
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.865 SNIP 1.647
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.752 SNIP 1.559
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.954 SNIP 1.749
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.77 SNIP 1.787
Comparisons of auditorium acoustics measurements as a function of location in halls (A)

In a measurement tour of nine U.S. concert halls measurements were made at 30 or more combinations of source and receiver position in each hall. Each of the three measurement teams (the University of Florida, the Danish Technical University, and the National Research Council of Canada) made parallel measurements of a number of modern room acoustics quantities using different equipment and measurement procedures. These results are compared on a seat-by-seat basis and the differences are explained in terms of earlier systematic studies of the effects of measurement procedure details. The measurement results were also used to examine the influence of different measurement equipment and measurement procedures on the within hall variations of the various acoustical quantities. [Work partially supported by the Concert Hall Research Group.]

General information
State: Published
Organisations: Department of Electrical Engineering
Authors: Bradley, J. S. (Ekstern), Gade, A. C. (Intern), Siebein, G. W. (Ekstern)
Pages: 2265-2266
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Main Research Area: Technical/natural sciences

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Web of Science (2017): Indexed yes
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Scopus rating (2016): CiteScore 1.83 SJR 0.749 SNIP 1.27
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.802 SNIP 1.437 CiteScore 1.77
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 0.788 SNIP 1.423 CiteScore 1.8
Web of Science (2014): Indexed yes
Effects of measurement procedure and equipment on average room acoustic measurements

This paper reports the results of a measurement tour of nine U.S. concert halls. Three measurement teams, from the University of Florida, the National Research Council of Canada, and the Technical University of Denmark, made parallel sets of measurements using their own equipment and procedures. In some of the halls measurements were repeated using the procedures of the other teams to make it possible to separate the effects of different equipment and different procedures. The paper will present position-averaged results from the three teams and will discuss reasons for the
differences observed. [Work partially supported by the Concert Hall Research Group.]

**General information**

State: Published
Organisations: Department of Electrical Engineering
Authors: Gade, A. C. (Intern), Bradley, J. S. (Ekstern), Siebein, G. W. (Ekstern)
Pages: 2265-2265
Publication date: 1993
Main Research Area: Technical/natural sciences

**Publication information**

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- BFI (2017): BFI-level 2
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- BFI (2016): BFI-level 2
- Scopus rating (2016): CiteScore 1.83 SJR 0.749 SNIP 1.27
- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 2
- Scopus rating (2015): SJR 0.802 SNIP 1.437 CiteScore 1.77
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 2
- Scopus rating (2014): SJR 0.788 SNIP 1.423 CiteScore 1.8
- Web of Science (2014): Indexed yes
- BFI (2013): BFI-level 2
- Scopus rating (2013): SJR 0.705 SNIP 1.966 CiteScore 2
- ISI indexed (2013): ISI indexed yes
- Web of Science (2013): Indexed yes
- BFI (2012): BFI-level 2
- Scopus rating (2012): SJR 0.763 SNIP 1.622 CiteScore 1.75
- ISI indexed (2012): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 2
- Scopus rating (2011): SJR 0.695 SNIP 1.642 CiteScore 1.68
- ISI indexed (2011): ISI indexed yes
- Web of Science (2011): Indexed yes
- BFI (2010): BFI-level 2
- Scopus rating (2010): SJR 0.754 SNIP 1.528
- Web of Science (2010): Indexed yes
- BFI (2009): BFI-level 2
- Scopus rating (2009): SJR 0.783 SNIP 1.717
- Web of Science (2009): Indexed yes
- BFI (2008): BFI-level 2
- Scopus rating (2008): SJR 0.848 SNIP 1.633
- Web of Science (2008): Indexed yes
- Scopus rating (2007): SJR 0.865 SNIP 1.647
- Web of Science (2007): Indexed yes
- Scopus rating (2006): SJR 0.752 SNIP 1.559
- Web of Science (2006): Indexed yes
- Scopus rating (2005): SJR 0.954 SNIP 1.749
- Web of Science (2005): Indexed yes
- Scopus rating (2004): SJR 0.77 SNIP 1.787
A statistical analysis of architectural features and detailed objective acoustical measurements made in eight concert halls and several multi-use rooms in their concert configuration will be presented. A method for evaluating the architectural features of rooms that affect their acoustical properties was developed. Architectural features of interest include both room average values and more-detailed subdivisions of surfaces including shape, volume, height, width, and sound absorption properties of materials. Regression modeling was performed for individual source–receiver paths as well as for entire rooms. Measurements data from all three teams were used in the models to assess the sensitivity of the models to expect variations in measurements. The results were compared to the previous work of Barron, Gade, and Hook among others.

[Work supported by the National Science Foundation and Concert Hall Research Group.]
During a 6-yr period, detailed room acoustical measurements have been carried out in 35 halls in Denmark and in other European countries. By subjecting these data to statistical analyses, it has been possible to confirm old and establish new relationships between design variables and the position-averaged acoustical data. The results are presented in the form of linear, multiple regression formulas that may be used to predict the values of the newer measures of level, clarity, spaciousness, and musicians' conditions on the orchestra platform in halls with given RT and geometry.
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<td>State: Published</td>
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<tr>
<td>Organisations: Department of Electrical Engineering</td>
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<tr>
<td>Authors: Gade, A. C. (Intern)</td>
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<tr>
<td>Pages: 1857-1857</td>
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<tr>
<td>Publication date: 1991</td>
</tr>
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<td>Main Research Area: Technical/natural sciences</td>
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<td>Volume: 89</td>
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<tr>
<td>Issue number: 4B</td>
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<td>ISSN (Print): 0001-4966</td>
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</table>
Can ensemble condition in a hall be improved and measured?

In collaboration with the Danish Broadcasting Corporation an extensive series of experiments has been carried out in The Danish Radio Concert Hall with the practical purpose of trying to improve the ensemble conditions on the platform for the resident symphony orchestra. First, a series of experiments in a 1:20 scale model indicated that among several suggested means the following would be the most effective and acceptable: (a) changing the shape of the sidewalls in the platform area in order to make them reflect sound back to the musicians more effectively; (b) lowering and redesigning of the ceiling reflectors; and (c) changing the position of the orchestra on the platform. These variables were then tested in full scale experiments in the hall including subjective evaluation by the orchestra in order to verify their effects under practical conditions. New objective parameters, which showed very high correlations with the subjective data, also made it possible to compare the improvements with conditions as recently measured in famous European Halls. Besides providing the needed results, the experiments also shed some light on how musicians change their criteria for judging acoustic quality depending on the experimental situation—a fact which had become evident from our previous research on musicians’ room acoustic conditions.
Projects:

Investigation of the relationships between the subjective assessment and objective parameters of music listening spaces

Department of Electrical Engineering
Period: 15/10/2017 → 14/10/2021
Number of participants: 4
Phd Student: Wincentz, Jakob Nygård (Intern)
Supervisor: Brunskog, Jonas (Intern)
Gade, Anders Christian (Intern)
Main Supervisor: Jeong, Cheol-Ho (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

CAHRISMA
The CAHRISMA project (Conservation of the Acoustical Heritage by the Revival and Identification of the Sinan’s Mosques’ Acoustics) is a three-year project financed by the EU. The purpose of the project is to study the acoustics of old Byzantine churches and mosques built by the ancient Turkish architect Sinan. A new measuring program was developed for the acoustic measurements in the rooms. The program uses a sweep technique previously developed and used at DTU. In short, an omnidirectional loudspeaker emits a sinusoidal sweep signal in the room, and the response of the room is simultaneously recorded with a two-channel microphone. The sweep signal is emitted and recorded through an audio card (Roland Audio Canvas UA-100) connected to a PC, using a commercial multitrack recording software (N-Track studio), and the recorded sweep is stored on the hard disk of the PC. The sweep response is then deconvolved with the inverted sweep signal, the result being the impulse response of the room. From the impulse response the different objective room acoustic parameters are calculated in the program. The average reverberation times measured in six rooms are listed in the table above. Acoustic models of three churches (Hagia Sophia, Saint Irene and Sergius & Bacchus) and three mosques (Süleymaniye, Selimiye and Sokullu) have been developed in ODEON. These rooms have a high geometrical complexity with spherical and cylindrical shapes dominating the rooms, especially large domes and numerous columns.

Department of Acoustic Technology
Period: 01/02/2000 → …
Number of participants: 4
Project participant: Gade, Anders Christian (Intern)
Christensen, Claus Lynge (Intern)
Weitze, Christoffer Andreas (Intern)
Project Manager, organisational: Rindel, Jens Holger (Intern)

Room acoustic measurements using Brüel and Kjær equipment
The Department of Acoustic Technology cooperate with Brüel & Kjær on modifying a hand held analyser, so that it can be used for more detailed room acoustics measurements (other than reverberation time) according to the new ISO 3382 and to IEC 286-16, of which the latter specify measurement of speech intelligibility according to the RASTI method.

Department of Acoustic Technology
Brüel & Kjær A/S
Period: 01/09/1999 → …
Number of participants: 1
Project Manager, organisational: Gade, Anders Christian (Intern)

Objective measures for listener envelopment
The correlation between different objective measures and subjective responses regarding "envelopment" of the listener by the sound in concert halls is investigated in laboratory experiments. The work is carried out in cooperation with Lily Wang
whose stay at AT is financed through an ASA Hunt post doctoral Research Fellowship.

Department of Acoustic Technology
Period: 01/03/1999 → 29/02/2000
Number of participants: 1
Project Manager, organisational:
Gade, Anders Christian (Intern)
Project

**Noise from neighbours - with focus on low frequencies**

With an increase in the use of light building constructions, problems have arisen at low frequencies where these types of constructions unlike the traditional heavy constructions cannot provide sufficient sound insulation. The measurement methods of today's building regulations do not consider frequencies below 100 Hz, and thus problems often appear in new buildings even when they comply with the demands in the normal frequency range. The purpose of the project is to evaluate the annoyance caused by a change in the low frequency level below 100 Hz by the use of subjective listening test. Frequency filters for five construction types, ranging from light to heavy constructions, have been created and applied to sound examples of three types of noise, two of impact noise and one of airborne noise. The presentations represented building constructions that would produce the same measurement results with the normal methods, although the A-weighted levels were different. Listening test were carried out with 25 test subjects, each of whom evaluated 24 presentations twice. The experiments have shown that an increase in the level at low frequencies produces greater annoyance, and thus it can be concluded that the traditional measurement methods are no longer adequate and a revision should be considered. One of the conclusions was that female subjects appeared to be much more annoyed by noise than male subjects.

Department of Acoustic Technology
DELTA
Period: 01/11/1997 → 30/04/1999
Number of participants: 4
Project participant:
Rindel, Jens Holger (Intern)
Mortensen, Frank Rysgaard (Intern)
Gade, Anders Christian (Intern)
Project Manager, organisational:
Jacobsen, Finn (Intern)

**Financing sources**
Source: Unknown
Name of research programme: Ukendt
Amount: 979,000.00 Danish Kroner

Department of Electrical Engineering
Spatially extended sound equalisation in rooms at low frequencies
Period: 01/09/1996 → 31/03/2000
Number of participants: 4
Phd Student:
Orozco, Arturo (Intern)
Main Supervisor:
Jacobsen, Finn (Intern)
Examiner:
Gade, Anders Christian (Intern)
Hald, Jørgen (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Selvfinansierende (privatist)
Project: PhD

**Effects of procedure and equipment on room acoustic measurement results**

Based on acoustic measurements from concert halls in which data have been collected by the Department of Acoustic Technology and other researchers in parallel, the differences between the results from the different laboratories are investigated. The work aims at recommendations regarding procedures for carrying out room acoustic measurements in
assembly halls. The project has been carried out together with National Research Council, Ottawa, Canada, and Statsbygg, Oslo, Norway.

Department of Acoustic Technology
Period: 01/08/1993 → 31/12/1996
Number of participants: 1
Project Manager, organisational:
Gade, Anders Christian (Intern)
Project

**Relationships between room acoustic data and concert hall design**
The purpose of this project is to improve the general knowledge about how size, shape and other geometric design variables influence the acoustic conditions of assembly halls like concert halls, theatres, multipurpose halls, churches etc. This year, renewed analysis of a data base (now containing more than 50 halls) has been carried out. The results obtained so far have confirmed most of the earlier results but have also revealed new relationships. Thus, it has now been possible to find some of the geometrical factors governing the rate of attenuation in sound level with distance from the stage.

Department of Acoustic Technology
Period: 01/05/1992 → …
Number of participants: 2
Project participant:
Rasmussen, Jørgen (Intern)
Project Manager, organisational:
Gade, Anders Christian (Intern)
Project

**Acoustics and geometries of concert halls**
This investigation attempts to reveal general relationships between room geometry and the acoustic properties in concert halls through statistical analysis of the data available in our existing data base. The examined objective acoustic parameters for audience are EDT, ts, LEF, C, G, G(r) (Rate of Spatial Decay [dB/10 m]), and for musicians, EDTP (EDT measured on the podium) and ST1. The acoustic parameters are averaged over frequency and position before the analyses. This year correlation analysis, principal component analysis and multible linear regression analysis have been carried out in order to see if these methods were able to reveal further information on the interaction between room geometry and acoustic properties. Besides, new geometrical parameters were included in the analyses; some were taken from newer literature and some were developed within the project. Also, two general and flexible room models were made in the simulation program ODEON, one rectangular model and one fanshaped model, in which single geometrical parameters were varied in an attempt to verify the regression models. For the acoustic parameters the correlation analysis showed that often many of the geometrical parameters had a good correlation with the acoustic parameters or with the difference between the parameter and its expected value according to diffuse field theory. Furthermore, the principal component analysis revealed complicated interactions among the geometrical parameters. From the simulations in ODEON it was generally found that the altered geometrical parameter showed the same effect on a current acoustic parameters as found from the regression models. The similarity between the ODEON calculations and the regression models was more distinct for acoustic parameters not related to reverberation time (ie parameters for which no value can be predicted via diffuse field theory).

Department of Acoustic Technology
Department of Electrical Engineering
Period: 01/01/1992 → …
Number of participants: 2
Project participant:
Weitze, Christoffer Andreas (Intern)
Project Manager, organisational:
Gade, Anders Christian (Intern)
Project

**Variable acoustics by means of electronics**
The work focuses on investigating the possibilities and limitations of electronic reverberation enhancement systems. The natural acoustic conditions will limit the degree of realism of the intended acoustic variations, particularly when such systems are installed in small halls. This year an experimental system was built in one of the auditoria at DTU in order to create a large set of stimuli for subjective experiments for investigating the subjective effects of reflections and reverberation generated in such systems. Most of the practical work was carried out by a master thesis student, Frank Rysgaard Mortensen, who also carried out preliminary listening tests. These tests confirmed the quality of the recorded stimuli for use in future experiments.
Department of Acoustic Technology

Period: 01/01/1991 → 31/12/1999

Number of participants: 1

Project Manager, organisational:

Gade, Anders Christian (Intern)

Project