Variable Acoustics means Variation of Reverberation Time – does it?

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Introduction

It generally is recognized that the acoustics of a room are not defined by its reverberation time only. For variable acoustics, however, the variation in reverberation time still is the commonly used quantifier of the effectiveness of the variation. This leads to the impression that variation of reverberation time is essential for effective variable acoustics. Acting as the acoustic consultant for a theatre renovation project, we were confronted with a client who required optimum acoustic performance for both opera and non-reinforced drama in the same house, but did not want to implement variable acoustics. Discussions with the client learned that their opposition to variable acoustics was in the expected complexity of the provisions, not only during construction, but also in operation and maintenance. A simple system was proposed to influence the early reflections, but without change of reverberation time.

Background

Theater am Goetheplatz is oldest and largest of the 4 theatres of the Theater Bremen. The current theatre was erected in 1950 on the location were before the 'Staatstheater' was located. [1] The theatre was renovated before in 1973/1974 but at the end of the 20th century there was a need for a full renovation of the interior of the auditorium and an upgrading and extension of the foyer areas.

Design goals

In discussions with the client and users of the theatre it was brought forward that in general the existing acoustics of the theatre were OK, but there were some points that needed attention. Summarized these were:

- there was insufficient coverage in the centre of the stalls
- the support in the orchestra pit was insufficient
- given the focus on music programming, a somewhat longer reverberation and more warmth was desirable

Although the programming covers an extensive range from Opera and Operetta but also Musicals utilizing sound reinforcement and non-reinforced Drama, the client expressed clearly that a system for variable acoustics, either mechanical or electronic, was not desired. The acoustics had to be optimized for Opera/Operetta but at the same time had to offer a good environment for Drama. Extensive discussions with the client on these contradictory requirements led to the compromise that a small adjustable reflector above the orchestra pit would be acceptable.

Existing acoustics

Before the renovation started, the acoustics of the existing theatre were measured. The results from the measurements supported the remarks from the client. The reverberation time of about 1.2 s at mid-frequencies was short for Opera and also exhibited a negative Bass Ratio resulting in a 'thin' sound. The insufficient coverage was illustrated by the large variation in Clarity over the seating area. C80 varied from about -1 dB to +4 dB while C50 varied from -4 dB to +1.5 dB. Counterintuitive; the lowest values for Clarity were found in the stalls, closest to the stage.

Analysis

Looking at the geometry of the room, the shape of the ceiling, introduced in the renovation of 1973/1974, appeared not very beneficial for the current use. Also the basic shoebox shape and the relatively light weight wall panelling could be related to the remarks on the acoustics.

Acoustic measures

The renewal of the interior of the auditorium was used to correct the observed shortcomings by implementing the following acoustic measures:

- enlargement of the room volume and shape of the ceiling
- introduction of a reflector above the orchestra pit
- shape and diffusion of side walls
- composition of wall panelling and ceiling
- diffusion in orchestra pit

These measures are elaborated below:

Enlargement of room volume

The ceiling, as it was introduced with the previous renovation, had 2 effects; the sound was projected strongly towards the balconies and the room volume was reduced. This resulted in both a short RT and a poor coverage in the stalls. By introducing a new ceiling the room volume is increased by app. 15% while the shape – in combination with the new reflector – intends to create a more even sound distribution. A comparison between the old and the new ceiling with reflector is given in figure 1.

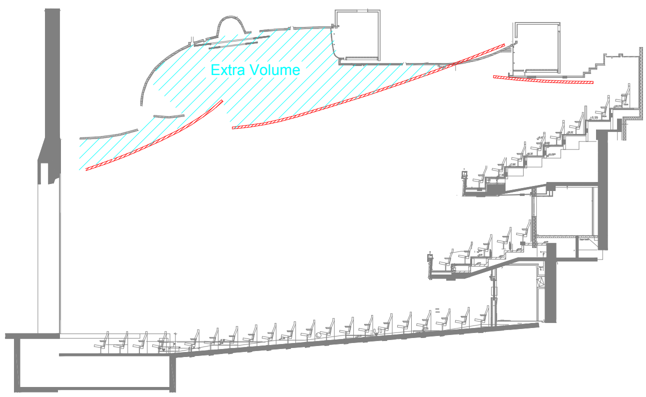

Figure 1: New section of auditorium, the previous ceiling shape is shown in red, the hatch illustrates the created extra room volume.

Reflector

The reflector above the orchestra pit consists of two sections: a fixed element (closest to the proscenium) and a - smaller - adjustable part which can be set in either a 'speech' or 'music' setting. Figures 2 through 4 illustrate the support due to the reflector and ceiling for the medial sound for a number of situations.

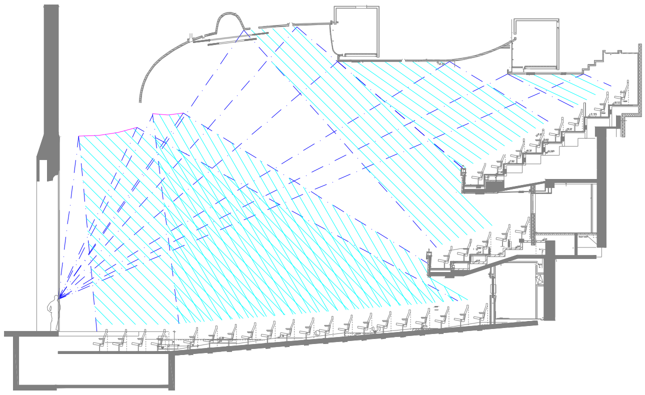

Figure 2 Reflector in Opera setting and singer located in the proscenium opening

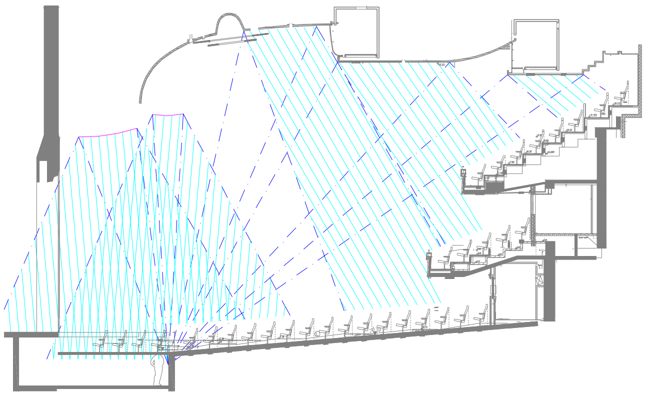

Figure 3 Reflector in Opera setting and instrument located at the first row of the orchestra

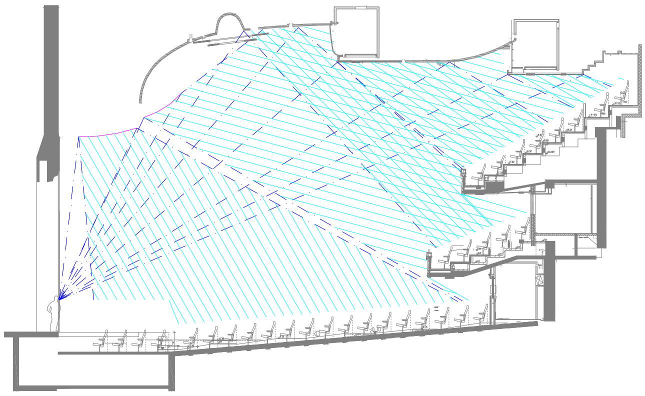

Figure 4: Reflector in the speech setting and an actor in the proscenium opening

It has to be noted that in this production theatre, drama is performed on the forestage, in front of the proscenium, hence the forward positions of the actors in these schemes. The hatching suggests the projection of the reflector and the ceiling for the various source positions.

Other measures

The width of the hall, in relation to the stage opening and the requirement for theatre-technical facilities (lighting) on both sides of the stage opening, as well as aesthetic considerations, limit the possibilities to shape the side walls. Within these conditions, the following acoustic measures were incorporated:

Parallel wall elements in the technical towers on both sides of the stage opening.

These surfaces improve the "support" and envelopment for both musical performances and speech theatre. Combined with the sound reflector, these wall elements form a 'Proscenium arch', as it is to be found frequent in traditional opera halls.

Vertical diffusion elements at the side walls.

The stage opening, technical towers and the width of the hall dictate to a considerable degree the basic form of the side walls. The resulting basic form (staggered Fan shape) is acoustically not optimal. Without additional measures it will result in a concentration of sound into the rear of the hall and a lack of coverage in the middle section. To compensate for this, vertical diffusing elements were installed at the side walls. These elements provide a highly scattering effect, in particular in the horizontal plane. This way the sound is distributed more evenly over the depth of the hall.

Composition of walls and ceiling

Before the renovation, excessive low frequency absorption was present in the hall due to the light structure of the previous wall lining. The ceiling and all wall panelling were removed, not only to facilitate the new shapes, but also to allow for a heavier build-up to minimise low frequency absorption. The new introduced wall panelling consists of a multilayered construction composed of 2 layers of plasterboard finished with wood veneered MDF panels. The ceiling was constructed from 3 layers of gypsum board. Both the wall panels and the ceiling had a surface mass in excess of 30 kg/m².

Orchestra pit

Orchestra pits are notorious for their acoustic problems. Too loud and no envelopment combined with a poor coupling to the hall. As in this situation the stage configuration was not to be changed; there were only limited possibilities to improve the orchestra pit acoustics

The proscenium arch created by the reflector and the parallel wall segments in the technical towers provides a better support and feedback from the hall.

To further optimize the conditions in the pit, rear and side walls under the overhang were provided with QRD diffusers. By doing so, the direct first reflection from these walls is reduced, time smeared and distributed over a larger angle. This reduces the perceived loudness, makes instrument placement less critical and improves the envelopment.

Simulations

The acoustic design was supported by computer simulations using Catt Acoustic V8.0. These simulations were used extensively to optimize wall and ceiling shapes and the optimum positions of the reflector. A 3D impression of the computer model is represented in figure 5.

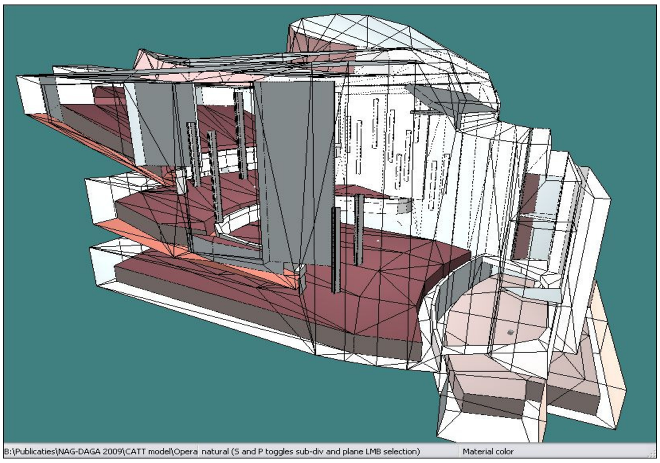

Figure 5: 3D impression of Computer model showing reflector in opera setting.

Results

Once the hall was completed, extensive measurements were done to establish the achieved acoustics. The measurements were performed using Dirac 3.1 software and an omni directional source in accordance with ISO 3382, ISO 140 and DIN 52210. Measurements were taken for a number of source and microphone positions as indicated in figure 6. These positions were as much as possible the same as those used for the measurements in the pre-renovation situation and as used in the computer modelling.

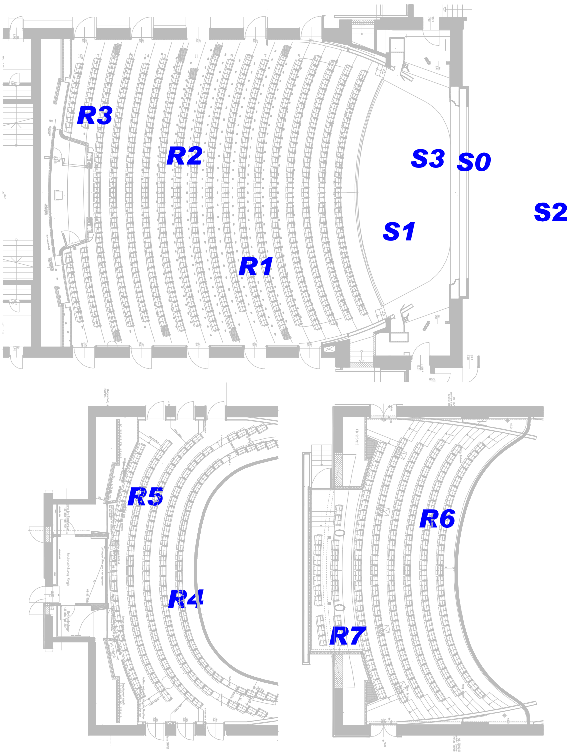

Figure 6: measurement positions - R=receiver S=Source

Reverberation

Figure 7 shows the measured T30 in the new configurations compared to the pre-renovation situation. The increased RT, particularly at low frequencies, is obvious and in line with the increased room volume. Also in line with the prognoses, it shows that the setting of the reflector has virtually no influence on the reverberation time. However, the influence of the reflector does show in the EDT (fig. 8), particularly at 1 kHz and 2 kHz where EDT is significantly longer for the opera setting than for the speech setting.

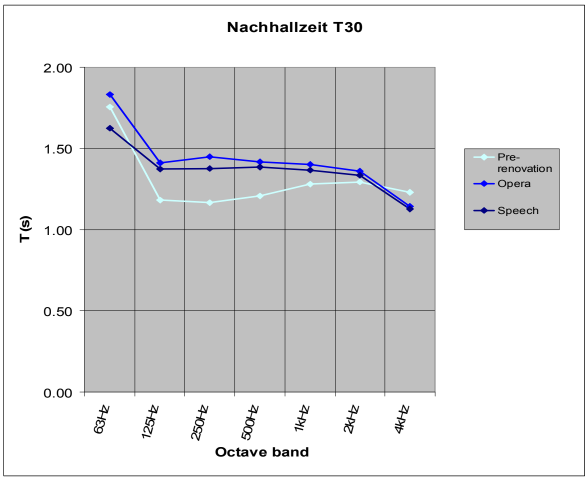

Figure 7: Measured reverberation time before and after the renovation

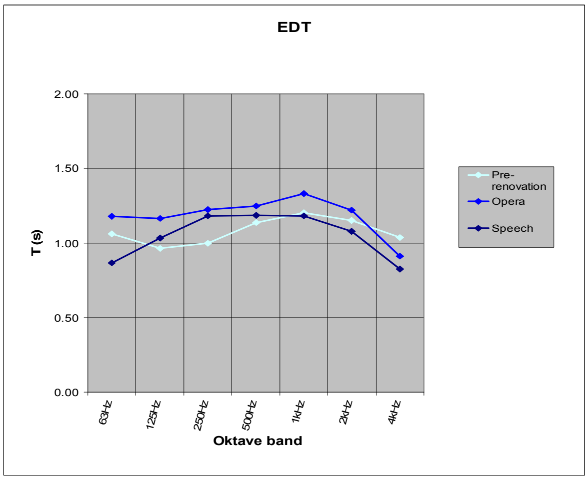

Figure 8: Measured Early Decay Time before and after the renovation

The delayed build up of reverberation in the opera configuration is even more clearly illustrated in the values of Centre Time (fig. 9). For all octave bands, Ts is 15% to 20% higher for the opera setting than it is for the speech setting.

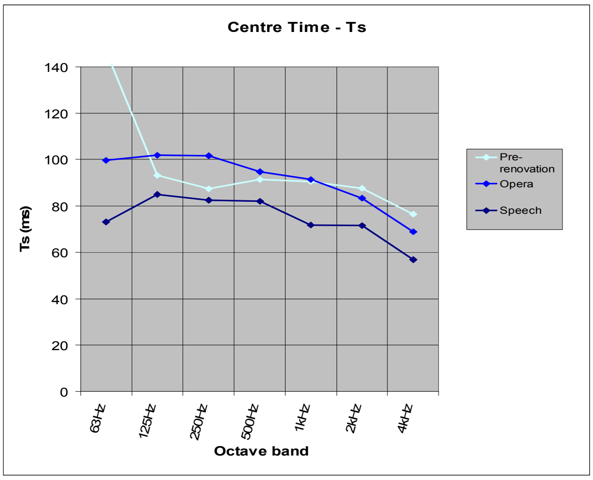

Figure 9: Measured Ts before and after the renovation

Clarity and intelligibility

Most obvious, however, is the effect of the reflector illustrated by the values for Clarity. Fig 10 gives both C80 and C50 (room averaged) for the Opera and speech setting compared to the previous situation. Figure 11 and 12 give C80 and C50 respectively for the individual seats, averaged over the source positions. Here it is clear that the variation in C80 has significantly reduced and now is constant within 2 dB over the entire seating area. For C50, the overall average improvement is about 0.5 dB, more significantly, the weakest seats have achieved an improvement of about 3 dB compared to the old situation. This is also reflected in the values for STI (fig. 13). It is clear that particularly the previous weakest seats have benefitted the most from the modifications.

Please note that the magenta and yellow curves are related to the most forward positions in the stalls. This is the area were the most improvement in Clarity is achieved and were before the most complaints were about.

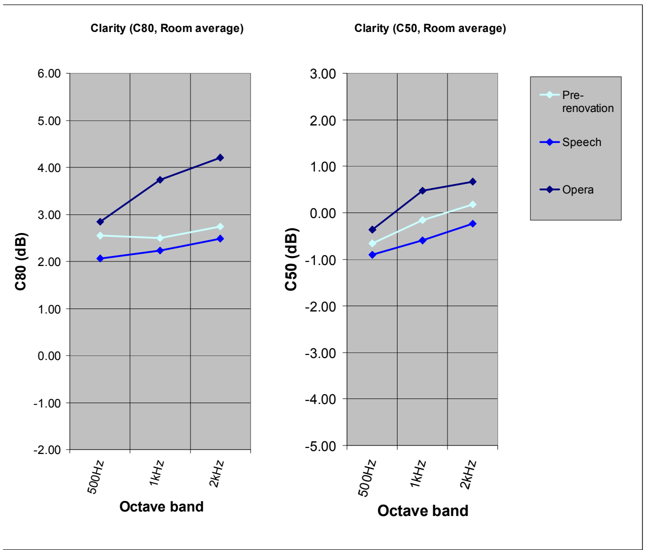

Figure 10: Measured Clarity before and after the renovation

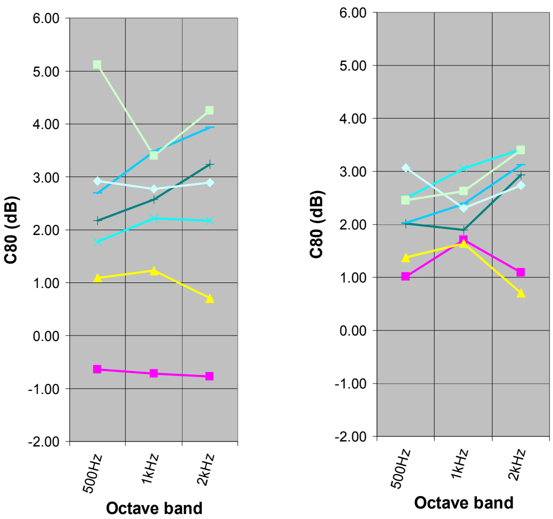

Figure 11: Opera configuration; Clarity (C80) pre-renovation (left) vs. after renovation (right)

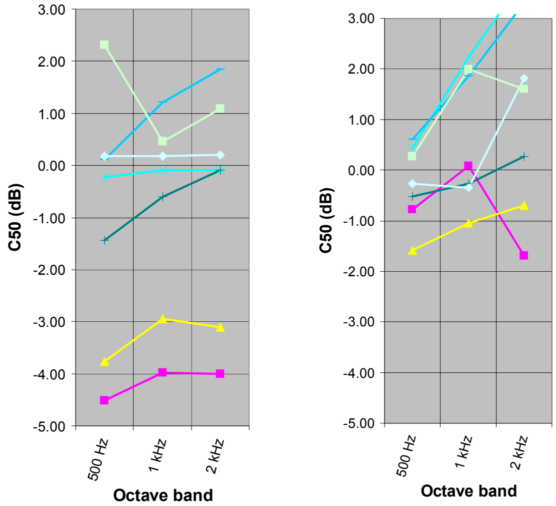

Figure 12: Speech configuration; Clarity (C50) pre-renovation (left) vs. after renovation (right)

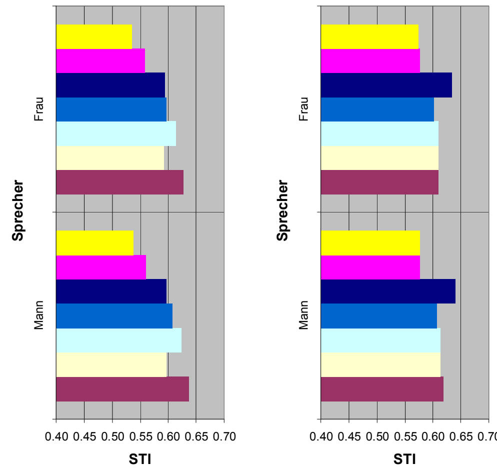

Figure 13: Speech intelligibility; pre-renovation (left) vs. after renovation - Speech configuration (right)

Conclusion

By the use of a, simple, adjustable reflector, and taking into account the specific source positions, the acoustics of the theatre can be optimized for either Opera or Drama. Shaping the build-up of the early sound results in a perceivable different acoustic environment, although the reverberation time does not change. A variation of about 1 dB in C50 and 1.5 dB in C80, at a reverberation time of 1.4 s, effectively changes the auditorium from a speech theatre to an opera house. In addition, other acoustic problems like the poor coverage in the stalls and poor pit conditions have been solved too.

After the renovation, the acoustics have been received very favourably, not at least by the orchestra which favours the pit condition. The success of the theatre has been expressed by the critics of 'Opernwelt' by electing the theatre 'Opernhaus des Jahres' in 2007.

References

[1] http://de.wikipedia.org/wiki/Theater_Bremen