THE ACOUSTICS OF A QUARRY, WHO NEEDS AN ACOUSTICIAN?

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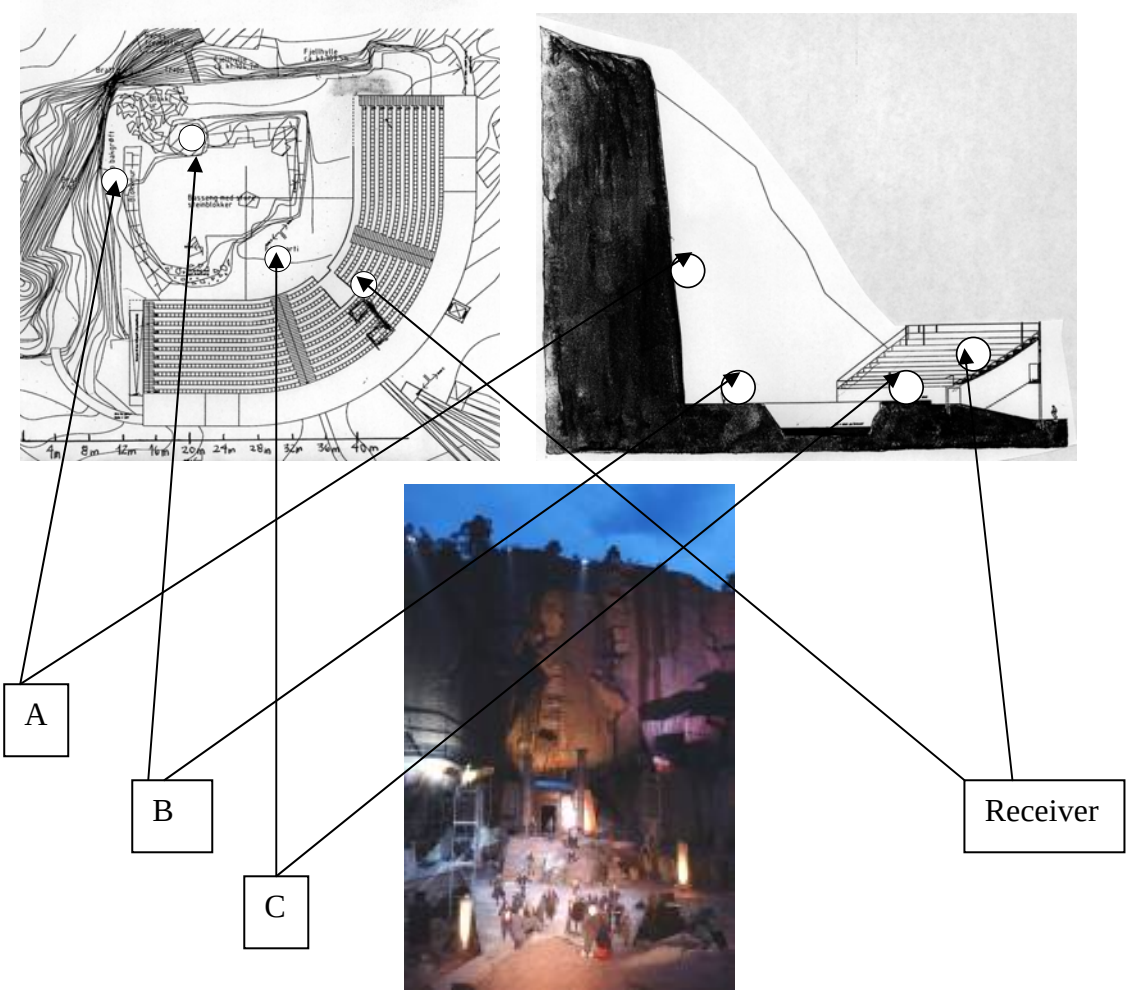
ABSTRACT
The paper gives information and measurements of the acoustics of an outdoor theatre in a quarry in Fjæreheia, Grimstad, in the southern part of Norway. The site is well known for its natural acoustics.

The reason for the good acoustics is not an “arkeztra” platform like the old greek amphi- theatres, but massive stonewalls at the rear of the huge “stage”. This theatre gives the actors the possibility of adjusting the voice and the direction of head in a very elegant manner, and use echoes as an effect in the performance. The acoustic measurements indicate that one should not use omni-directional loudspeakers when measuring details of such theatre acoustics.

THE OUTDOOR THEATRE

Fjæreheia is an outdoor theatre in a stone quarry in the south of Norway, near the small town Grimstad, where Henrik Ibsen in his early days spent some years as a chemist’s apprentice. .

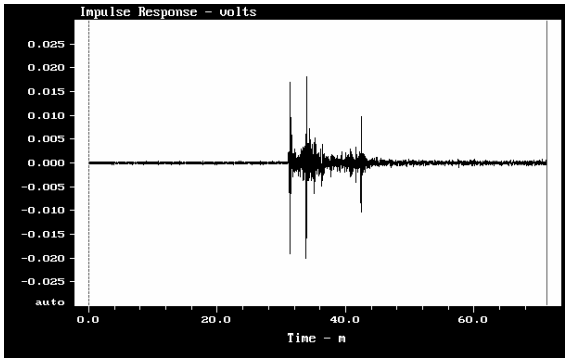


The outdoor theatre is run by Agder Theatre, a regional theatre situated in Kristiansand.
The site has been used for theatre performances for some years, with a temporary amphi made of wood.
I did acoustic measurements for this situation and experienced the performance of Ibsen: "Peer Gynt", 1998, and assisted that the new amphi, made in concrete in 1999, secured the natural good acoustics.
(The theatre reports that the new amphi has even better acoustics, for the 99-season of the same performance). "Peer Gynt" was done totally without electronic amplification (except for sound effects and some music playback), even if the distance from the most remote actors position is more than 45m. The most surprising experience was that the actors speech, at the longest distances, was by all means the "clearest".
The close reflections from the stone back wall should be a good exercise for all students of scenography.

ACOUSTIC MEASUREMENT RESULTS

Equipment:
- MLSSA,
- Stage Technology pre-amp,
- Fostex SPA-11 (directional) loudspeaker,
- AKG (omni) microphone.

A) Actor close to the stonewall:

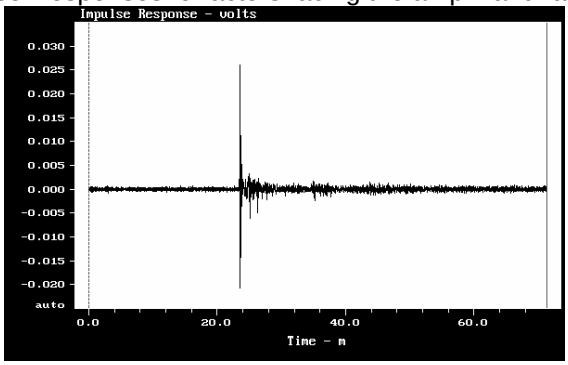


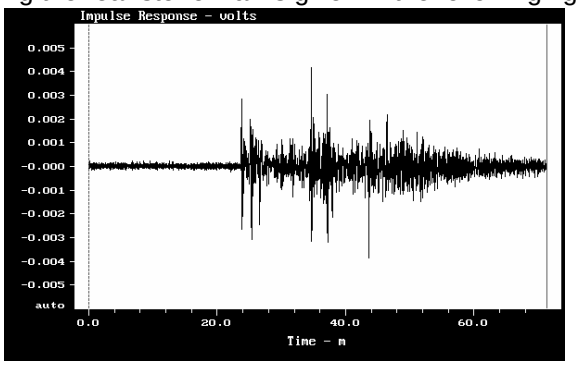
Impulse Response of actor close to the stonewall. (x-axis = sound path in meters)

The Impulse Response shows a strong, close reflection from the stonewall (within 3 m). This reflection is as strong as the direct sound. Such close reflections will give coloration *[1], [3], [4]*, *[5] [6],* but this does not give any problems for the speech transmission, and the coloration appears "natural" for the site.
The reflection arriving 12 m after the direct sound comes from the opposite stonewall, and does not give any clear echo, and increases the speech intelligibility. Actors placed at these far positions were extremely well understood by the audience.

B) Actor at centre - stone- position:

Impulse Responses for actors facing the amphi and facing the rear stone-wall is given in the following figures



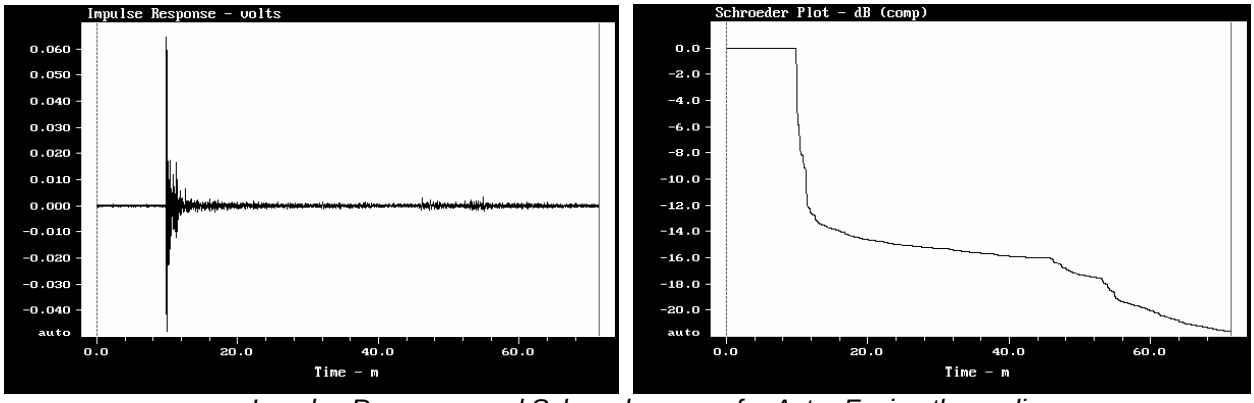


Impulse Response from "centre" a)=Facing amphi b)=Facing stone walls

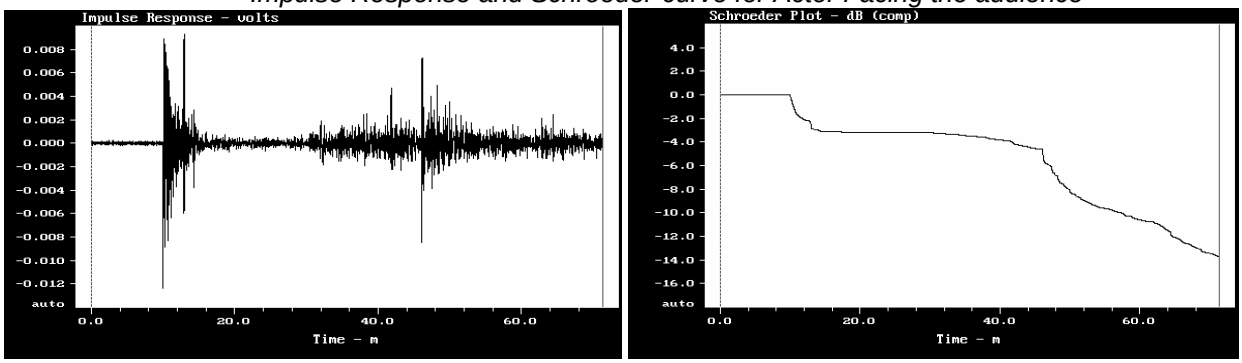
Facing the audience, the actor does not get much acoustical "help". When facing the stonewalls, we see strong reflections 10m after the direct sound, from the stonewalls, that will increase the speech intelligibility. After some 20m we see the reflections from the corner between the stonewalls. These reflections give

echoes. The actors carefully used these effects during performance. *(conf. [2]* regarding natural "effects" controlled by actors/musicians movements).

C) Actor in front of the amphi



Impulse Response and Schroeder-curve for Actor Facing the audience



Impulse Response and Schroeder-curve for Actor Facing the stonewall

The theatre had the experience that the front positions (like C) of the actors were in fact the most problematic with respect to speech intelligibility, even though they are placed very close to the amphi. This is because these positions do not get any close reflections, due to the massive absorption in the ranked audience amphi. On the other hand, strong "outbursts" from this position, when facing the stonewall, was very dramatic. The actor has the possibility to change between "close/near" and "broad/reverberant".

It is also interesting to notice that actions on the front stage gave broad "stereo"-reflections from the stonewalls. This was very well used in the big "wedding" scene of Peer Gynt, which was sonically magnified and broadened due to these reflections. (Happily, such reflections also appear for the audience applause!)

DISCUSSION/ACOUSTIC PARAMETERS (1000 Hz, 1/1 octave)

	C50	"STI"	"Alcons"	**EDT**	**RT** (-5, -25 dB)
A) Close to Stone Wall	10.8	*0.7*	*2.9*	0.2	1.1
B) On Centre Stone					
Towards audience	4.5	*0.6*	*5.3*	1.1	1.1
Towards stone wall	-0,4	*0.6*	*7.3*	0.6	1.1
C) In front of Audience-Amphi					
Towards audience	8.0	*0.9*	*1.9*	1.7	1.0
Toward Stone Wall	-1.6	*0.6*	*5.6*	1.2	0.9

The measured C50 corresponds very well with the experiences from the performance. Source position A, close to the stonewall, is extremely clear, (it also gives high volume/strength at the receiver positions). For source position B, on the centre stone, we see that the C50 is reduced when facing the stonewall, compared to facing the audience. This is because of the reflections after some 20m etc, giving echo etc., discussed above. However, in practical use, with trained actors, the benefit of extra volume/strength more than compensates this lack of clarity, so that as a total, the direction of the actor facing the stone walls is better than facing the audience, for this centre-stone-position.

The measurements of Speech Transmission Index (STI) and Loss of Consonants (Alcons%) are not in agreement with the standards for such measurements, but might give some information when comparing the two measurements taken in the different directions, from the same source points. We see that STI is best for the source position A at the longest distance, except for the position C, very close to the receiver. For the other source positions, the STI values are about equal. The results for Alcons% show about the same trends as C50 above, this means that they do not show the actual, experienced need for facing the stone wall to get enough reflections to give enough strength/volume at the listener.

The use of the non-omni directional loudspeaker gives results that clearly show the difference in reflection behaviour experienced when the actor turns his head. As shown in the Impulse Responses, the sound decays are often far from linear, and the measured reverberation times give only a slight indication of the acoustic environment. In standardised room-acoustic-measurements, omni directional loudspeakers are often preferred, in order to give reproducible results. Reproducibility might, however, be somewhat contradictory to finding interesting acoustical results. Using an omni directional loudspeaker would give results somewhat between the results of our measurements, and one would not find the detailed information on how the actor can change between "clear/direct" and echo/reverberation just by turning his face. Such changes were truly demonstrated during the performance.

CONCLUSION

This paper shows acoustic measurements of an outdoor theatre with highly acclaimed speech acoustics. It is found that, in order to investigate the acoustics, one must investigate the Impulse Responses in detail. The nuances of the acoustics of this highly mentioned outdoor theatre could not have been judged by measurements with an omni directional loudspeaker, and investigating the common room acoustic criteria alone.

The actors can change both reverberation, delay, timbre/coloration and other "audio effects", just by turning their head.

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