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THEATRE OF THE SANCTUARY OF ASKLEPIOS AT EPIDAURUS AND THE THEATRE OF ANCIENT EPIDAURUS : OBJECTIVE MEASUREMENTS AND COMPUTER SIMULATIONS

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Abstract

Many Greek and Roman theatres are intensively used nowadays hosting a variety of performances. Part of the objectives of the EU funded project "ERATO" (Identification, **E**valuation and **R**evival of the **A**coustical heritage of ancient **T**heatres and **O**dea) was to process and discuss topics related to the theatres' modern use such as restoration of acoustical properties, use of amplification etc. Under "ERATO", acoustic measurements and computer simulations of ancient Greek and Roman theatres were conducted. The theatres that were included were located in Italy, Turkey and Jordan. In the outcomes of "ERATO" [1], specific recommendations and guidelines have been proposed concerning the modern use of Ancient Greek and Roman theatres [2].
In our study, it was decided to expand the analysis in two theatres intensively used nowadays, which this time would be located in Greece; The Theatre of the Sanctuary of Asklepios at Epidauros and the Theatre of Ancient Epidauros. Apart from in situ measurements and computer simulations, listening tests were also conducted using material binaurally recorded at the theatres during live performances.
In the present paper the results of in situ measurements in various source-receiver configurations at both theatres are presented and the different source positions are compared. Moreover, the ODEON models of the 2 theatres are used in order to investigate the effect of the addition of a stage on the acoustic properties of the theatres.

Keywords
Theatre of Epidauros, Theatre of Ancient Epidaurus, Objective measurements, ODEON simulations.

1. Introduction

In the outcomes of the EU funded project "ERATO" [1], specific recommendations and guidelines have been proposed concerning the modern use of Ancient Greek and Roman theatres [2]. In this paper, the recommendations that suggest "restoration of the stage" and "positioning of the sound sources on the proscenium near the skene wall" are investigated by means of computer simulations and in situ measurements, respectively. The theatres under investigation are two theatres that are intensively used nowadays: The Theatre of the Sanctuary of Asklepios at Epidauros (from now on referred to as "Theater of Epidauros") and the Theatre of Ancient Epidauros.

2. Description of measurements and recordings

2.1 Instrumentation

For the measurements the DIRAC software v3.0 was used. The source used was a dodecahedron loudspeaker and the receiver an AKG stereo microphone.The signal that was used was an exponential sweep with a duration of 10,9 seconds.

2.2 Source and Receiver positions

The chosen receiver and source positions are shown in figures 1 and 2, respectively.

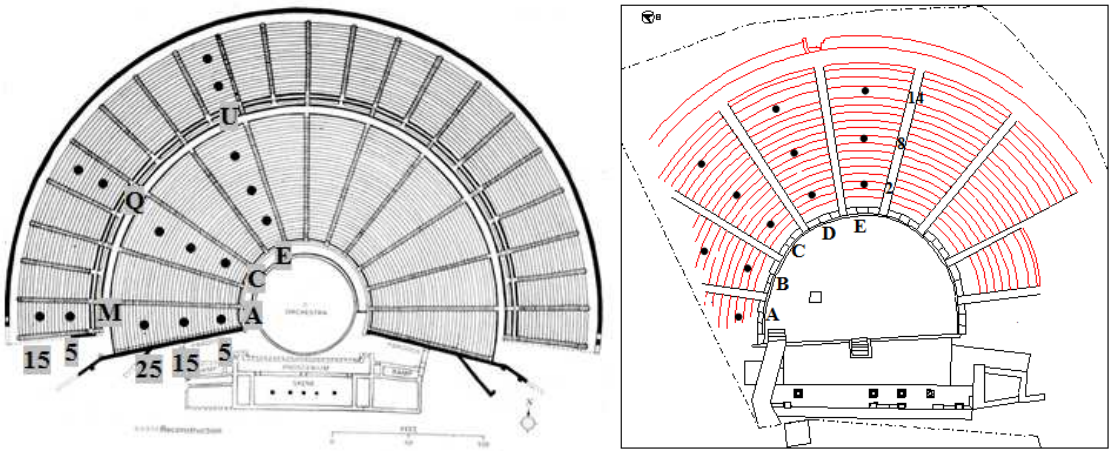

Figure 1 - Plan views of the Theatre of Epidauros (left) and the Theatre of Ancient Epidaurus (right). The receiver positions are marked with black dots.

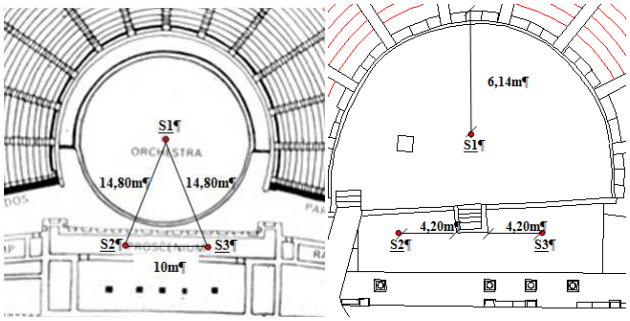

Figure 2 - Plan view of the *orchestra* and *skene* of Theatre of Epidauros (left) and the Theatre of Ancient Epidaurus (right). The source positions are marked with red dots.

For the Theatre of Epidaurus the height of the source at positions S2 and S3 was chosen to be 3,80m; according to Vitruvius the height of the *logeion* in an ancient Greek theatre "ought to be not less than ten feet or more than twelve" [3]. Thus, by positioning the sources in that way, an effort of recreating the source positions indicated by Vitruvius was made; of course, the absence of a *skene* could not be compensated.
In the case of the Theatre of Ancient Epidaurus all source positions were at a height of 1,5m from the wooden construction that was covering the ruins of the *skene* and the whole *orchestra* at the time of the conduction of the measurements.

3. Investigating different source positions by means of in situ measurements

The results from sources S1 and S2 will be presented.

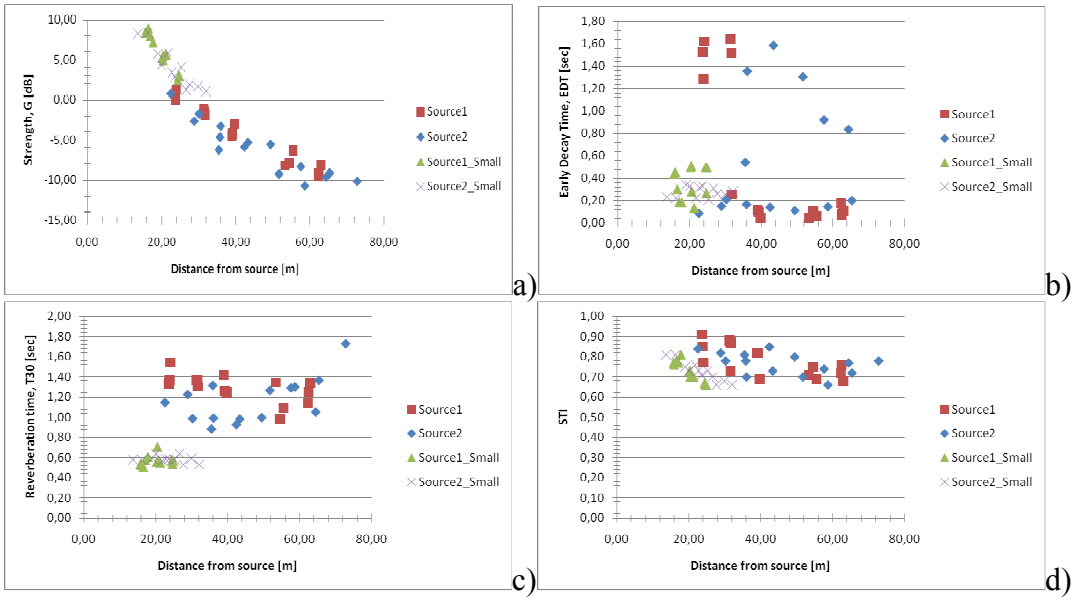

Figure 3 - G, EDT, T30 and STI versus distance in both theatres. Each point represents the average of the measured values at 500Hz and 1000Hz octave bands, for the specific source-receiver setup. The red and blue markers correspond to measurements at the Theatre of Epidaurus, while the green and purple correspond to measurements at the Theatre of Ancient Epidaurus

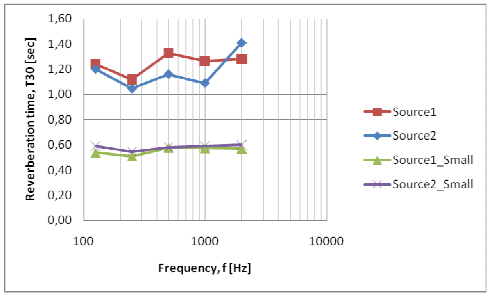

Figure 4 - T30 versus frequency in both theatres. Each point represents the average of the values measured in all receiver positions, for the specific octave band. The red and blue markers correspond to measurements at the Theatre of Epidaurus, while the green and purple correspond to measurements at the Theatre of Ancient Epidaurus

As expected, in both theatres G depends rather on the distance from the source, than the specific source position (Figure 3a). In free-field conditions the sound pressure level drops 6dB per doubling of distance. Due to the fact that the sound field in the space of both theatres is not "free" at all a less steep drop would be expected. Nevertheless, by comparing the points on figure 3a it seems that this is not the case in either of the theatres.
Looking at figure 3b one can observe that while for most source-receiver configurations at the Theatre of Epidaurus EDT is between 0,1 and 0,25, there is a number of outstanding points reaching in many cases values higher than 1 sec. The explanation is that in those cases the receiver is having quite strong reflections. Comparing Source 1 to Source 2 one can say that in the first case the receivers at the first 3 measured rows (ie. 5, 15 and 25) of the theatre are receiving the strong reflections, while in the second case after looking point by point into our dataset the outstanding points correspond to the receiver positions situated at the first *"kerkida"*. Depending on the level and time delay of those reflections comparing to the direct sound, they might be perceived as distinct echo; however, it must be stressed that the measurements were made when the theatre was unoccupied. In the case of the occupied theatre the absorption added by the audience would effectively reduce the amount of energy reflected to those positions.
At the Theatre of Ancient Epidaurus, on the other hand, the difference between S1 and S2 is around 0,1 to 0,2 sec in all receiver positions.
As far as Reverberation time is concerned for the Theatre of Epidaurus, when the source is positioned on the *orchestra* the values of T30 are generally higher comparing to position S2 (Figure 4), especially in the first 25 rows [Figure 3c]. This could be explained by the fact that in the absence of a *skene*, when the source is positioned in the back (where the *skene* used to be), more sound rays "escape" from the space of the theatre.
For the Theatre of Ancient Epidaurus there is no obvious dependency of T30 from the source-receiver distance [Figure 3c], while no matter where the source is, T30 is around 0,5-0,6 sec in the frequency bands from 125Hz to 2000Hz [Figure 4].
Last but not least, STI [Figure 3d] is not affected by the source position and it is over 0,65 for every source-receiver configuration at the big theatre. This observation justifies the fame of this theatre that a performance is intelligible even at the most remote seats. STI in the Theatre of Ancient Epidauros is also very high and independent both from source-receiver distance and source position.

4. Investigating the addition of stage by means of computer models

Both theatres were modeled in ODEON v8.5. In order to simulate "open-air" conditions, both models were surrounded by a totally absorbing box. The absorption coefficients were assigned to the surfaces by assigning different materials, in order to achieve as close match as possible between measured and simulated values in terms of Reverberation Time and Strength. All the materials that were used were found in the "Global Material Library" of ODEON v.8.5.

4.1 Theatre of Epidaurus

Looking at figure 5a the addition of the stage building does not affect much T30. It could be said that it reduces the dispersion of the values around a mean value of around

1,4 seconds, while G is increased in most positions by 1-2dB. EDT increases in all positions and the increase is more obvious as the receiver moves towards the positions which are further away from the source. As expected, the increase of EDT is followed by a drop of C80; in most positions by more than 7dB. However, STI remains between 0,6 and 0,7 even for the most remote positions.
Summarizing, by adding the stage building it is possible to compliment the reverberance of the theatre but not without paying the "price" of the reduction in clarity.

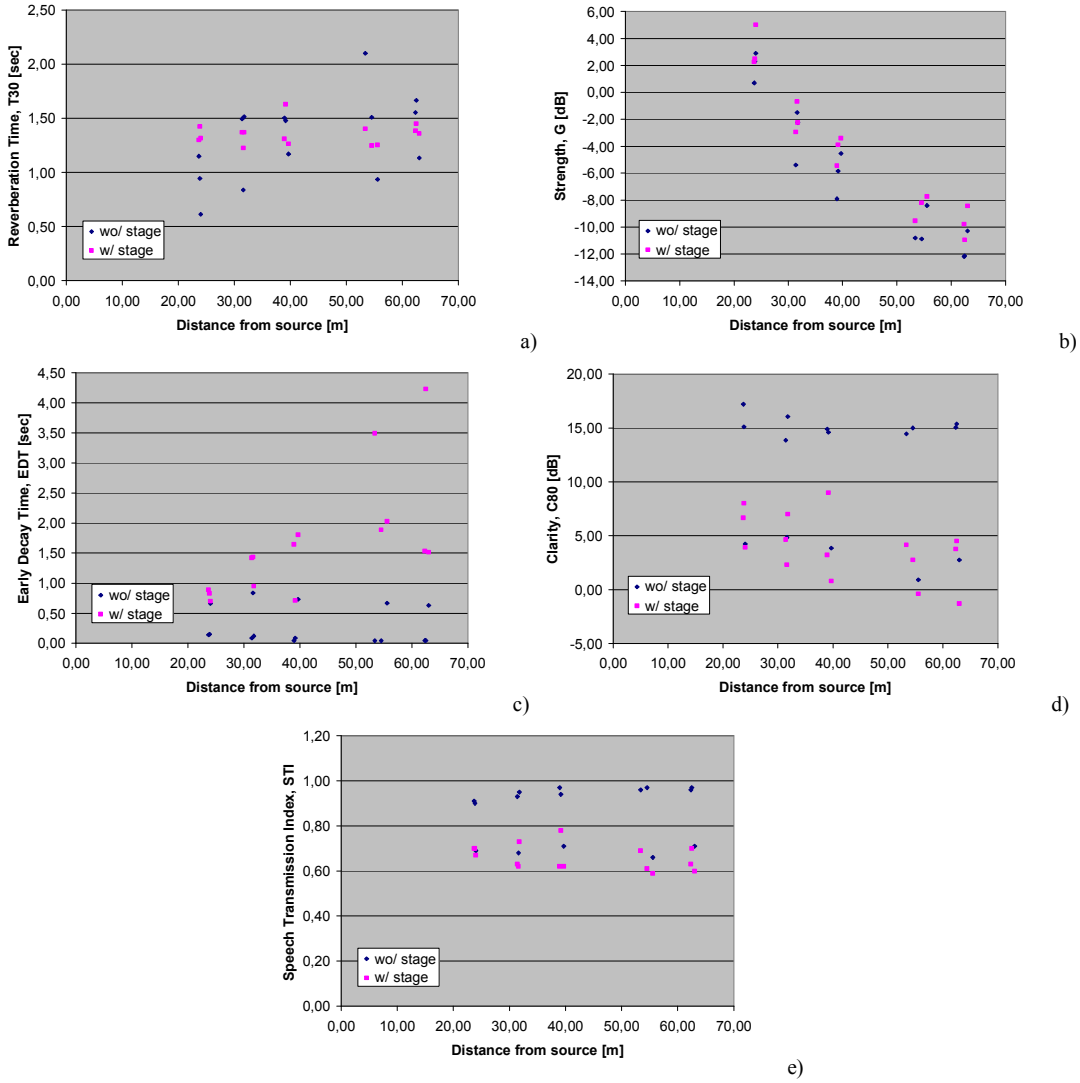

Figure 5 – T30, G, EDT, C80, STI vs distance at the Theatre of Epidauros. The source is positioned in the center of the *orchestra*. Each point represents the average of the values at 500Hz and 1000Hz octave bands, for the specific receiver position. The pink and blue dots indicate values obtained from the model of the theatre with and without stage, respectively.

4.2 Theatre of Ancient Epidaurus

Looking at figures 6 it is possible to see that the addition of a stage building increases the T30 by almost 0,2 seconds in most of the positions, while the values for G are increased around 2dB. EDT increases in general and as the receiver moves away from the source this increase becomes larger, exceeding 100% in the back rows of the theatre.

As expected, Clarity is decreasing and at the most remote seats it drops more than 6dB. However, in the case of this theatre as well, STI remains at levels between 0,66 and 0,72 which signifies *"Good"* intelligibility. However, taking into account that T30 and EDT are quite low even after adding the stage, the theatre is still too "dry" for hosting a non amplified musical performance.

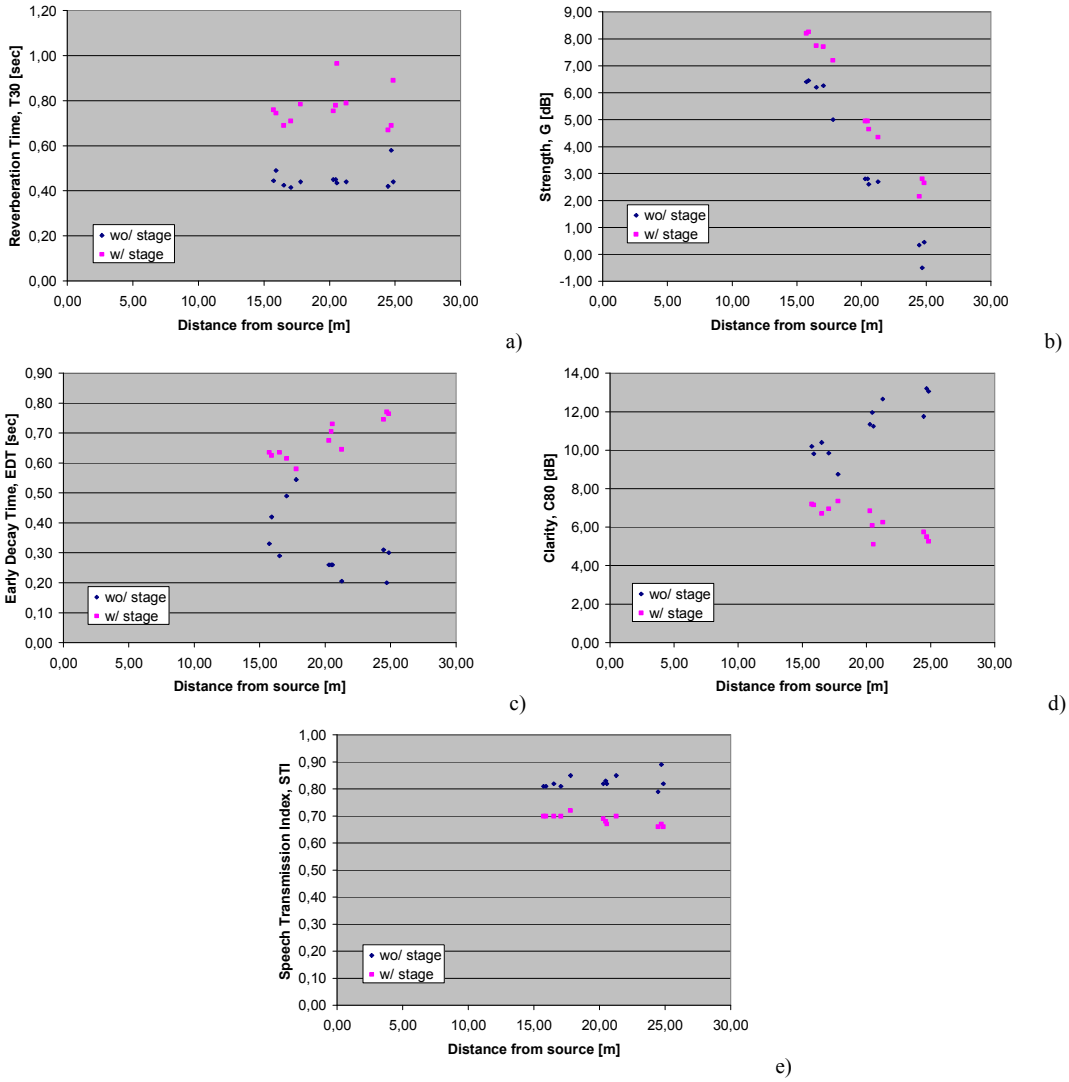

Figure 6 – T30, G, EDT, C80, STI vs distance at the Theatre of Ancient Epidauros. The source is positioned in the center of the *orchestra*. Each point represents the average of the values at 500Hz and 1000Hz octave bands, for the specific receiver position. The pink and blue dots indicate values obtained from the model of the theatre with and without stage, respectively.

5. Conclusions

Analysing the measured data for investigating different source positions we have concluded in the following:
At the Theatre of Epidaurus, by positioning the sound source where the *logeion* used to be when the *skene* of the theatre was intact, the high EDT values observed at the lower part of the *koilon* (below the *diazoma*) when the source was positioned at S1, were this

time observed at the theatre's first *kerkida*. Taking this fact into consideration S2 is to be preferred since the risk of undesirable echoes is limited to the first -and last- *kerkida*, which are also not so priviledged in terms of sightline. However, measurements in the occupied theatre are necessary in order to investigate if EDT values remain disturbingly high or if the extra absorption added by the audience reduces the amount of energy reflected to those points at acceptable levels.
Furthermore, a small increase in T30 values was observed when the source was positioned on the *orchestra*, especially in the first 25 rows. Last but not least, STI remained over 0,65 independent of the source-receiver configuration, reaching in many cases beyond 0,8!
For the Theatre of Ancient Epidaurus source position does not have an influence on the theatre's sound field.

Using the computer models we have investigated the effect of the addition of a stage at the theatres, if the source was to be placed on the *orchestra*. For the Theatre of Epidaurus, T30 and G do not increase much, while the effect is obvious on EDT and consequently on C80. However, even if C80 decreases STI still remains at quite high values around 0,65.
For the Theatre of Ancient Epidaurus, the addition of the stage has a positive effect on the sound field of the theatre making it more reverberant without compromising much on clarity. However, with T30 being less than 1,50 sec the theatre might still be considered too "dry" for hosting a non amplified musical performance..

References

[1]: "Identification, **E**valuation and **R**evival of the **A**coustical heritage of ancient **T**heatres and **O**dea"-**ERATO**: "Final Report: covering period from 1 February 2003 to 31 January *2006"*.
[2]: Michel Vallet, Bruno Vincent, Martin Lisa Nielsen, *"Report on the Assessment of the Virtual Environments"*, ERATO: Deliverable 9.4. November 2005.
[3]: Vitruvius, *"The Ten Books on Architecture",* Translated by Morris Hicky Morgan, Ph.D., LL.D., Dover Publications, Inc., New York.