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OINIADES ANCIENT THEATRE ACOUSTICS ASSESSMENT

George Cambourakis

Electrical & Computer Engineering Dept., National Tech. Univ. of Athens, Athens, Greece

Abstract

The Oiniades ancient theatre was built circa 330 BC with a second phase starting most probably circa 300-250 BC. It has almost concentric rows of seats with a capacity of 4640 spectators. For the assessment of the Oiniades ancient theatre acoustics the following procedure was followed: (1) An electronic model was built from the excavation initial drawings and on-site theatre geometry measurements. (2) Acoustic field simulation of the computer-restored theatre was studied and compared with on-site recitation experiences, (3) Extensive acoustic measurements were taken in the actual ancient theatre location in order to compare the simulation outcomes with the results of the measurements.

The electronic model for the Oiniades ancient theatre was built using AUTOCAD drawing program. The theatre geometry elements were transferred in the electronic model from the excavation drawings. From the restoration drawings, the photos of theatre remnants, and imaginary rendered architectural models, the “koilon” of the theatre can be measured precisely as there is adequate evidence of its geometry. Most of the theatre seating rows are preserved in such good condition that permits contemporary drama performances to be held. From the acoustic simulation of the theatre it was found that the theatre’s overall speech intelligibility is optimum for the majority of the seats. Furthermore, some indications about the acoustic performance for music performances are also provided.

1. Introduction

Oiniades (from "oinos"=wine or from the name of King "Oineas" of Kadydon) is an ancient city located about 5 Km from town "Katochi" in Akarnania (middle Greece). The Oiniades ancient theatre (Lat: 38.4093666 Lon: 21.1987960) was built circa 330 BC, in two phases, the second phase started most probably circa 300-250 BC. It has almost concentric rows of seats with a capacity of 4640 spectators. Since <kerkides> i.e. seating rows, were carved in the supporting rock, their number varies between 19 and 30. The step height between rows is about 40 cm and step width about 75 cm.

Intelligibility is a very important qualifier [2] [3] for the assessment of ancient theatre acoustics, given that speech was the main element of a theatrical performance. Nowadays there are many methods for quantifying intelligibility in a room or any other space. All methods try to find the number of the correctly understood words in a series by the average listener. Evidently, the result of any such measurement depends on the listener's capability to recognize the words, the speaker's ability to pronounce the words correctly, and certainly the room acoustics. Also, we know from our experience confirmed from stringent measurements that the number of words per second that the speaker utters is of major importance in intelligibility tests. On the other hand, words belonging in a common phrase can be understood more easily than random words in a series. It seems that the human mind can fill in the missing acoustic information supposing that the next word is that with the greatest expectation. A simple method to estimate intelligibility is by counting the correct words that a small group of listeners writes down while hearing a speaker. This method has a limited use today but it is quite simple and there is no reason why it could not be applied in ancient times. Forming even small groups of listeners is quite expensive today. There are methods that estimate intelligibility by the assessment of the side effects of the acoustic phenomena. The rate that the acoustic energy is decaying in a room is of prime importance in measuring intelligibility while noise is a second parameter that could disturb flawless communication between speaker and listener. Usually the ratio of useful sound energy to the total available, is manipulated and a lot of criteria are developed.

2. Method

For the assessment of the Oiniades ancient theatre acoustics [1] the procedure mentioned henceforward was followed:
1) An electronic model was built from the excavation initial drawings and on-site theatre geometry measurements.
2) Acoustic field simulation of the computer-restored theatre was studied and compared with on-site recitation experiences.
3) Extensive acoustic measurements were taken in the actual ancient theatre loca-tion in order to compare the simulation outcomes with the results of the measurements [5].

In what follows we will go through the steps of the procedure mentioned above analyzing and commenting on the findings from the computer simulated acoustic field of the theatre [7].

The electronic model for the Oiniades ancient theatre was built using AUTOCAD (version 2000) drawing program for the registration of the theatre geometrical elements in the computer. The theatre geometry elements were transferred in the electronic model from the excavation drawings, and as it is obvious, the precision of the model is not better than that of the excavation findings. From the restoration drawings, the photos of theatre remnants, and imaginary rendered architectural models it can be seen that the <koilon> of the theatre can be measured precisely as there is adequate evidence of its geometry. Most of the theatre seating rows <Edolia> is preserved in such good condition that permits contemporary drama performances to be held, although archaeologists disagree with this practice. Other details concerning the scenic building in all its phases were transferred into the computer from prof. Savvas Gogos' restoration drawings.

Table 1 – Positions and types of sound sources.

Source	*Position*			*Source axis angles*			*Source Type*
	x	Y	z	Ver.	Hor.	Rot	
S1	0	0	1.7	0	180	0	Male loud voice
S2	0	-11	4,24	0	180	0	Male loud voice
S3	0	8	1,7	20	180	0	Male loud voice
S4	-3	-11	4,24	0	120	0	Male loud voice
S5	0	27	11	-60	0	0	Male normal voice
S6	0	-16	1,1	0	180	0	Male loud voice
S7	0	-16	4,24	0	180	0	Spherical
S8	-8	0	1,7	0	120	0	Male loud voice
S9	-22	-3	1,7	10	120	0	Male loud voice
S10	8	0	1,7	10	120	0	Male loud voice
S11	0	-6	1,7	10	180	0	Male loud voice

The origin of the coordinates is located in the orchestra center. The y axis is the theo-retical "symmetry" axis of the theatre. The z axis is in a vertical position to the ground. The x axis lies parallel to the scenic building

After the AUTOCAD model conclusion and the definition of the three dimensional entities (using 3Dfaces) of the theatre, the three-dimensional model was exported as .dxf file and subsequently imported into the acoustic simulation program EASE(v.3.0). A functional model was deducted laboriously from the initial .dxf file after it was adapted accordingly to the needs of the EASE modeling procedure. During the simulation phase the positions of the sound sources were defined and they are tabulated in table 1.

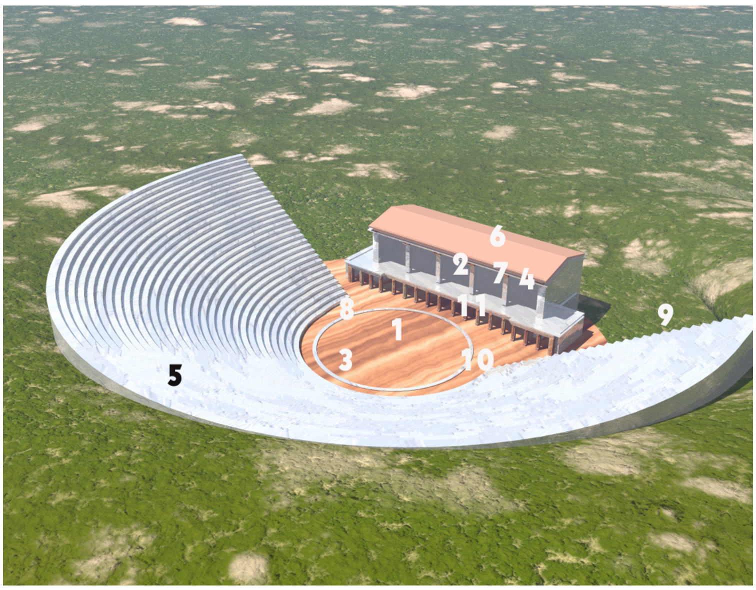

Figure 1 – Restoration model and positions of sources

3. Commenting on simulation results

- When the fictitious actor is in the same position with source S1 of the simulation, in the center of the orchestra, intelligibility criterion ranges from excellent, for the lowest 4 steps, good from 5th to 18th steps and fair for the rest (19th to 30th).This result is obvious seeing the panoramic depiction of the calculated intelligibility, in Fig.2. Good intelligibility from this position is confirmed from the clarity criterion C50 depicted in Fig.1a. All over the audience, C50 takes values greater than 0 dB, denoting that direct field is prevailing. Clarity criterion C7 gives a good clue that besides good intelligibility the position of the source S1 can be easily localized by the audience. Rephrasing the previous analysis, we can conclude on a firm ground that all the audience could understand a speaker located in the middle of the orchestra if he uttered his speech loudly enough.
- When the actor is transferred to S2 position (middle of the first floor of the scenic building) the intelligibility results for this position are depicted in Fig.3.This position is not good for acting since it is obvious that intelligibility deteriorates, in comparison to the results of position S1. In the upper steps, intelligibility becomes poor (Loss of consonants criterion [Alcons] increases to 15-18%). Intelligibility deterioration is evident in all the audience area, qualitatively characterized as "fair". Only the two lowest steps have "very good" intelligibility [Alcons 7-11%]. Intelligibility deterioration for S2 position is expected as the distance between the actor and the audience is increased. The clarity criterion C50 confirms that intelligibility does not take intolerable values.

Table 2 – Sound Pressure Levels at 1m distance from the source.

	Standard Frequencies (Hz)									
	100	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**
Male Loud Voice	57	57	59.67	62.33	65	67.33	69.67	72	71.67	71.53
Male normal voice	49	49	51	53	55	56	57	58	55.67	53.33
Spherical	80	80	80	80	80	80	80	80	80	80
	1000	**1250**	**1600**	**2000**	**2500**	**3150**	**4000**	**5000**	**6300**	**8000**
Male Loud Voice	71	69.67	68.33	67	64.67	62.33	60	57	54	51
Male normal voice	51	49.67	48.33	47	45.67	44.33	43	41.33	39.67	38
Spherical	80	80	80	80	80	80	80	80	80	80

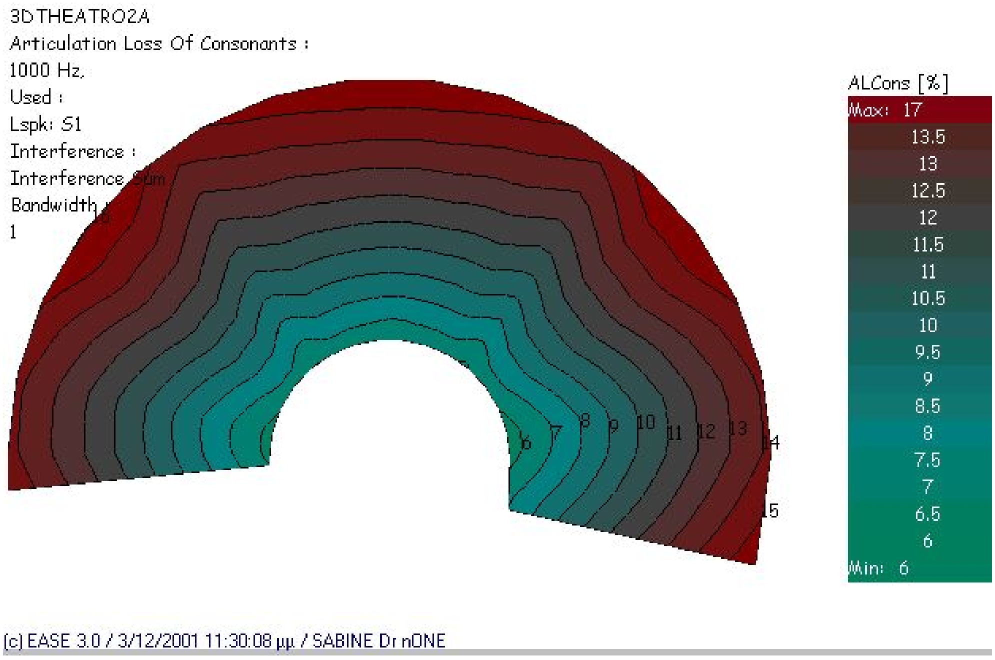

Figure 2 – Loss of Consonants diagram for source S1

- When the actor comes closer to the seats of the city powerful men <proedreion>, in other words he takes position S3, then we found that intelligibility becomes better than that achieved from position S1 in all the audience, except for the outer wings where it is “poor” [Alcons 15-18%]. Again an expected result as the sound source comes closer to the audience.
- S4 is located (see table2) on the first floor of the scenic building. This position gives “very good” intelligibility to the seats on steps 1-10th located on the left of <proedreion>, while half of the <koilon> experiences a drastic intelligibility deterioration [Alcons 15-18%].

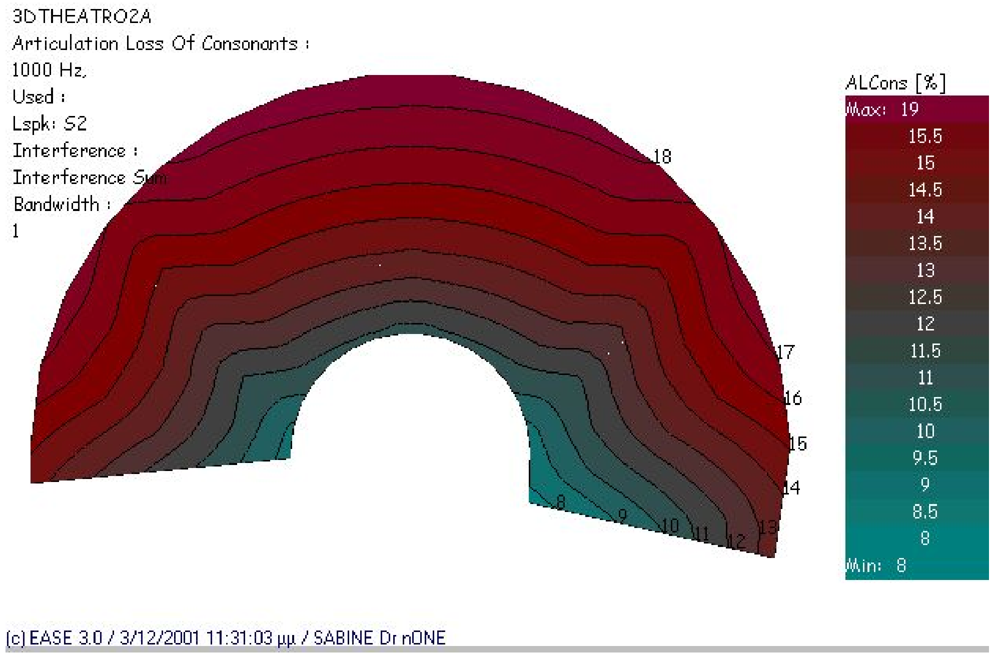

Figure 3 – Loss of Consonants diagram for source S2

- Source S5 (talking spectator) is unintelligible to all audience, except those positions located in its immediate vicinity. This could be seen easily from simulation results (unfortunately not sawn for brevity) where most of the seats have tremendous loss of consonants [Alcons >30%]. This result confirms that a spectator speaking in a normal voice does not disturb the performance but he adds to the audience noise [4]. If the audience noise is much less than the defined level then this noise source will become prominent.
- Concerning sources S6 and S7 we can easily predict that their intelligibility contours are alike with those from S2. These positions are invisible to the audience (inside the building). As a matter of course it is difficult to predict their acoustic characteristics as we have no evidence concerning the acoustical properties of the intervening materials. If these sources were musicians we could conclude that they would be heard with more richness and warmth than in other positions.
- With the actor in position S8 the part of the <koilon> located behind him and on his left has “very good” intelligibility while the part just opposite him from the 10th step and above has “poor”. This position gives us evidence of the combined effect of distance and source directivity on intelligibility. In this case the directivity of human voice is combined with the theatre geometry and gives this intelligibility distribution not easily predicted without the help of the computer [8].
- Intelligibility from source S9 (loud male voice) is “poor” to intolerable in all the audience except a small portion of the <koilon> located at the end of the “shadow” of the left wing edge. Raising his voice from loud to shouting, which means a Sound Pressure Level of 100 –110 dB, the actor can be heard clearly in all the audience except the “shadowed” portion. Intelligibility then is “excellent”. This position is easily localized by the audience. Confirmation of this comes from clarity criterion C7 which gives values greater than –15dB in all the theatre except the “shadowed” part.

- When the actor takes the position S10 symmetrical of S8 (with respect to the orchestra's centre) intelligibility is "excellent" for the 10 lowest steps in front of him, "very good" for the steps 11-22 and "good" for the rest. The steps behind him suffer an intolerable intelligibility, while the steps located on his left and slightly behind him have an intelligibility meriting from "very good" (lowest steps) to "poor" (upper steps).
- Source S11 offers "very good" intelligibility for all the audience except for the uppermost central steps where it deteriorates to "poor".

4. Conclusive comments

The acoustic simulation of the theatre can be summarized as follows:

- Overall speech intelligibility is optimum for the majority of the seats. Evidently, intelligibility depends heavily on the actor's voice strength and his articulation. Audience noise has to be as low as possible so that intelligibility attains useful values, at any case audience noise greater than that defined in the model is obtrusive and deteriorates intelligibility ratings accordingly. The audience model defined, allows for 25-30 whispering spectators. If the audience noise becomes greater, intelligibility deteriorates very soon, especially for the more distant seats or those behind the actor.
- Because of the structure of the reflections field (when the theatre is in full capacity) music is not favored. Wind instruments having slow attack and slow decay give better results concerning warmth and richness than plucked or percussive. These instrument qualities could be augmented if musicians were located inside the scenic building using its inherent reverberation for altering the attack and decay times by a small amount.

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