# Comparison between In-situ recordings and Auralizations for Mosques and Byzantine Churches

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**Abstract**: The **CAHRISMA** project (***C***onservation of the ***A***coustical ***H***eritage by the ***R***evival and ***I***dentification of the ***S***inan's ***M***osques ***A***coustics) investigates, among other things, the acoustics in some of the old churches and mosques in Istanbul. The present paper deals with acoustic computer simulations and in particular comparison between In-situ recordings and auralization obtained from simulations carried out in the ***Odeon*** program. Three of the rooms in the project - Sokullu, Süleymaniye and Saint Irene, were compared.

Two types of In-situ recordings have been made, one directly recorded in the room with a person performing, and another where measured binaural room impulse responses (BRIR) have been convolved with anechoic recordings. These two types of recordings have been compared with simulated auralizations in selected positions. The rooms in the comparison vary in size and reverberation time.

**Keywords**: Room acoustics**,** computer models, auralization, in-situ recordings

## 1. INTRODUCTION

As part of the **CAHRISMA** project a number of anechoic recordings have been made by the Italian partners from the University of Ferrara (UNIFE). These include a large number of signals typical for mosque services and one byzantine hymn, which has been used in the churches in the time of the Byzantium Empire. Furthermore in-situ recordings have been made in selected rooms (see below) investigated in the **CAHRISMA** project for selected positions. The anechoic recordings have been used to make auralizations from calculated binaural room impulse responses (BRIR) using the ***Odeon*** computer software. The calculated auralizations have been compared with the in-situ recordings and with measured BRIR (for two of the rooms) convolved with the anechoic recordings. The calculated auralizations made from the ***Odeon*** models have been made in the same positions as the in-situ recordings, and as far as possible with the same signals.

## 2. THE CAHRISMA EDIFICIES

In the following, data and pictures are seen for the Odeon models of the CAHRISMA edificies used for the comparison between auralization and in-situ recording.

### The Sokollu mosque

For the Sokollu mosque four in-situ binaural recordings have been made with the receiver positioned under the dome, and with four different source positions (see figure 1). Furthermore two different positions have been selected to compare measured BRIR convolved with anechoic signals with auralizations. These comparisons have been done for two different signals.

From figure 1 the different source and receiver positions for the ***Sokollu*** mosque are seen. The middle receiver is the one used for the in-situ recordings. The two other receivers are used for the measured BRIR convolved with anechoic signals compared with auralizations. Figure 2 shows two different source – receiver positions. The Sokullu mosque has an approx. volume of 5.700 $m^3$ and a $T_{30}$ (reverberation time) value of 2,8 sec. at 1000 Hz.

### The Saint Irene Byzantine church

In the Saint Irene Byzantine church one binaural in-situ recording was made, with the source and receiver placed on a stage (see figure 3 and 4). The ***Saint Irene*** church has an approx. volume of 39.200 $m^3$ and a $T_{30}$ value of 4,2 sec. at 1000 Hz.

From figure 3 and 4 the source – receiver position used for the ***Saint Irene*** is seen.

**The Süleymaniye mosque**

For the ***Süleymaniye*** mosque the in-situ recordings were done monaurally for one source position and four receiver positions. These recordings have been compared with auralizations. Since the in-situ recordings contain some background noise, a comparison with added noise to the auralization has been made. The noise is made from a looped sample from the in-situ recording. Furthermore two comparisons between measured BRIR convolved with anechoic signals and auralizations have been made. The ***Süleymaniye*** mosque has an approx. volume of 114.100 $m^3$ and a $T_{30}$ value of 5,9 sec. at 1000 Hz.

From figure 5 the different source and receiver positions for the ***Süleymaniye*** mosque are seen. The receivers used for comparison between measured BRIR convolved with anechoic signal and auralizations are marked. The other receivers are used for the comparison between in-situ recordings and auralizations. Figure 6 shows two different source – receiver positions.

In figure 7 an example of the first 0,4 sec. of a simulated BRIR from the ***Sokollu*** mosque is seen. The direct sound is seen to have the highest sound pressure level then following are all the reflections. Also a difference for the two ears is seen for the two impulses, giving the binaural 3D quality.

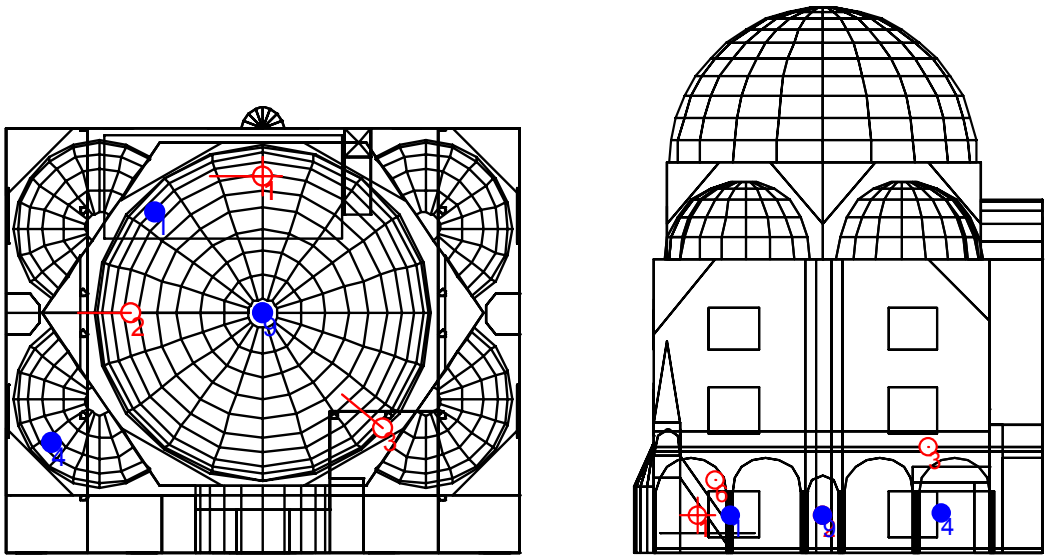

Figure 1: ***Odeon*** wire-frame models of the ***Sokullu*** mosque (seen from above and from the side) indicating sources (bright dot) and receivers (dark dot).

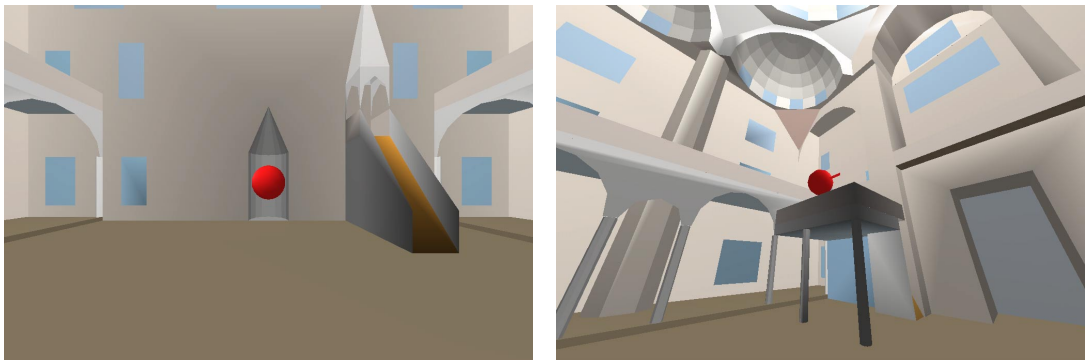

Figure 2: ***Odeon*** 3DOpenGL pictures of the ***Sokullu*** mosque showing two different source – receiver positions. The pictures are seen from the receiver position looking towards the source (dark dot).

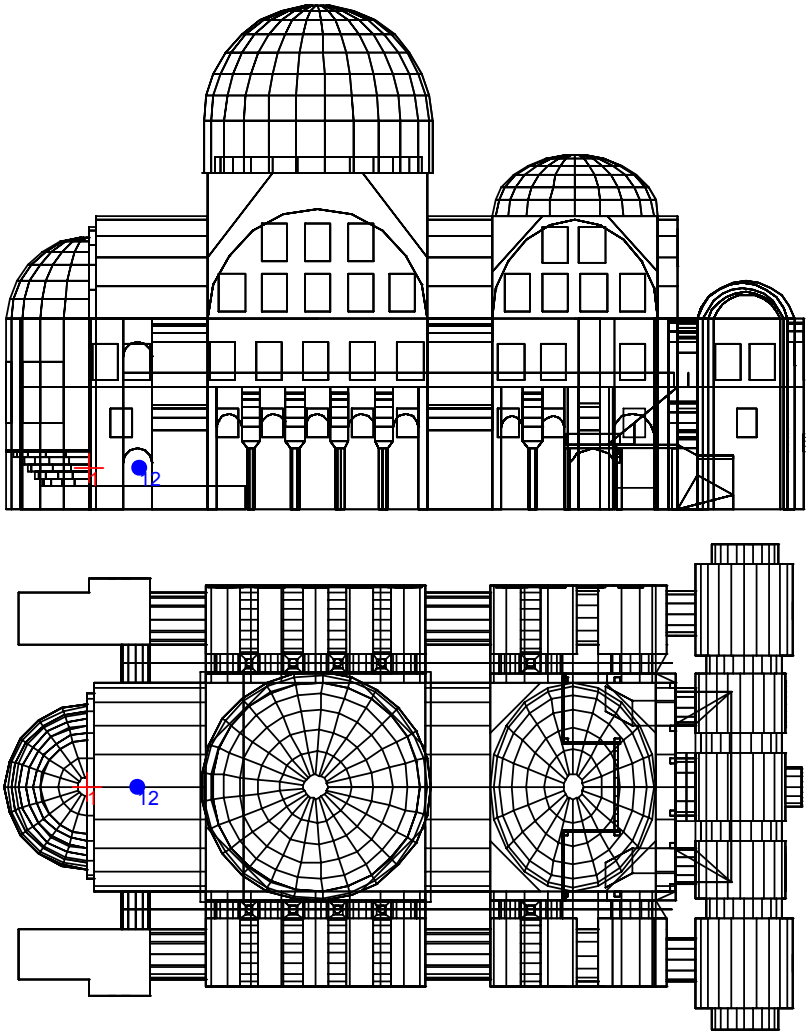

Figure 3: ***Odeon*** wire-frame models of the ***Saint Irene*** Byzantine church (seen from the side and from above) indicating source (bright dot) and receiver (dark dot).

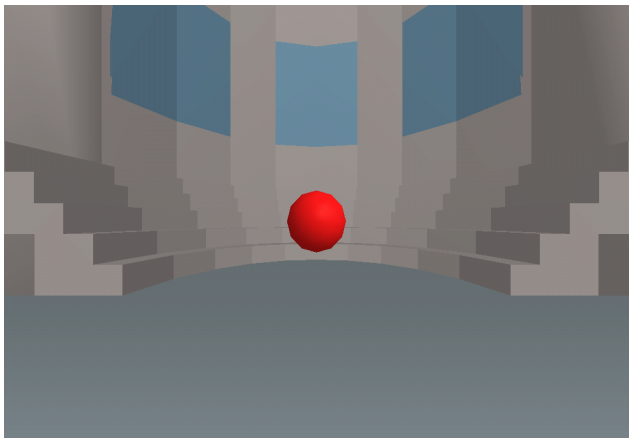

Figure 4: ***Odeon*** 3DOpenGL picture of the ***Saint Irene*** showing the source – receiver position. The picture is seen from the receiver position looking towards the source (dark dot).

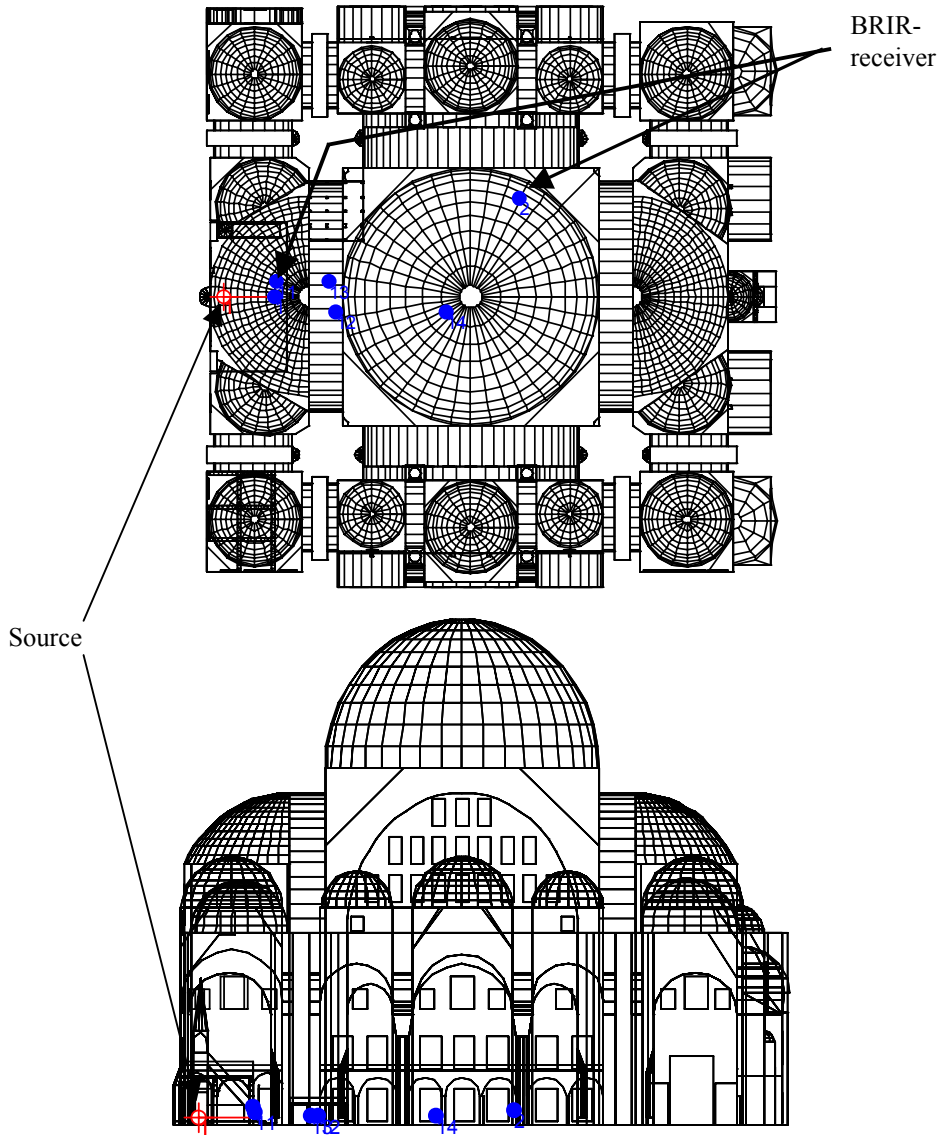


Figure 5: ***Odeon*** wire-frame models of the ***Süleymaniye*** mosque (seen from above and from the side) indicating sources (bright dot) and receivers (dark dot).

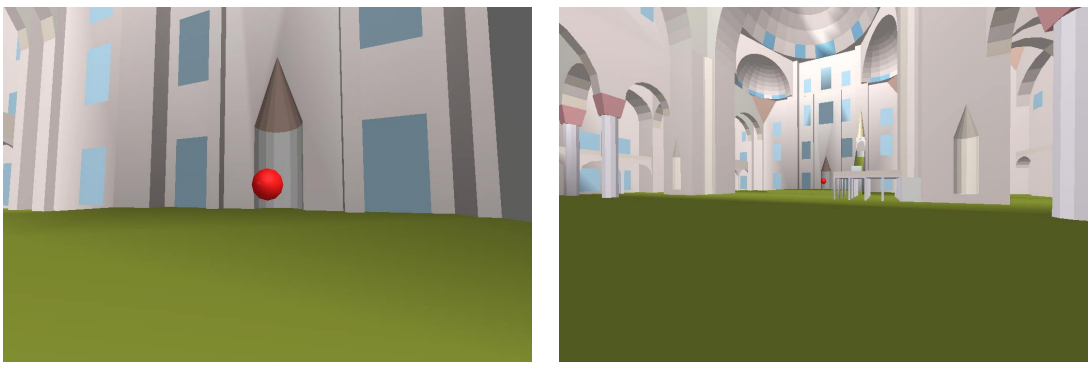

Figure 6: ***Odeon*** 3DOpenGL pictures of the ***Süleymaniye*** showing the source – receiver position. The picture is seen from the receiver position looking towards the source (dark dot).

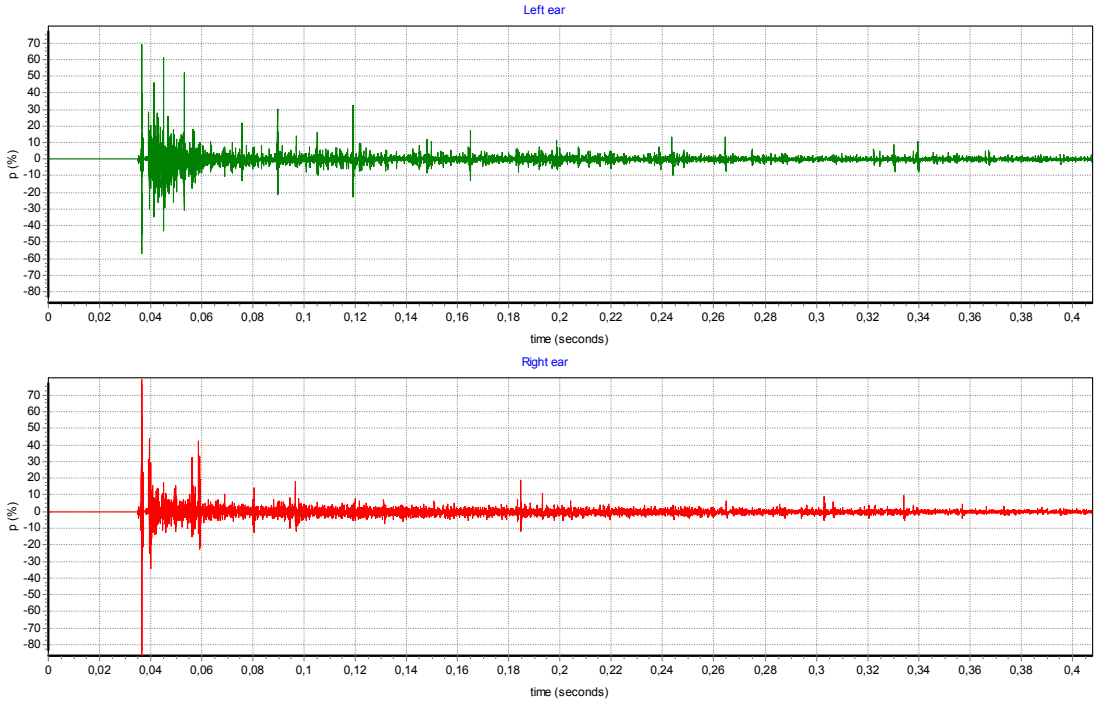


Figure 7: A simulated BRIR from one of the positions in the ***Sokollu*** mosque (the first 0,4 sec). The top is for the left ear and the low is for the right ear.

## 3. DISCUSSION

When comparing the in-situ recordings with the auralizations generally a high resemblance is heard, especially for the binaural in-situ recordings.

For the ***Sokollu*** mosque a high resemblance between the in-situ recordings (binaural) and the auralizations is heard, both for the perceived reverberation, the distance from source to receiver and the perceived 3D space. Some discrepancy is heard for the position where the source is placed higher than the receiver (see figure 2, right picture). The signal from the auralization seems to have a bit higher clarity than the in-situ recording. Some of the heard discrepancies could be explained by the fact that the raw signal (the sound from the person performing) is a bit different for the different positions for the in-situ recordings, due to the fact that the performer can not say/sing exactly the same every time. Where as the auralizations always uses the same anechoic signal, so the raw signal is always the same.

For the measured BRIR convolved with anechoic signals compared with auralizations, a good resemblance is also heard both for the perceived reverberation, distance from source to receiver and perceived 3D space. The recorded BRIR signals have less high frequency energy, which is caused by the imperfections in the used loudspeakers, which has a frequency spectrum that cuts off at high frequencies, when emitting the impulse in the room. So the simulated auralization is in fact more correct than the one from the measured BRIR.

For the ***Saint Irene*** byzantine church also a high resemblance is heard between the two signals for the perceived reverberation, the distance from source to receiver and the perceived 3D space.

The comparison for the ***Süleymaniye*** mosque is a bit different compared to the other edificies. As explained earlier the in-situ recordings are made monaural, so they will not have a 3D effect. Still it is possible to compare the perceived reverberation and distance. When comparing the signals a similar reverberation is heard, especially when the auralized signal including the noise is compared with the in-situ recording. The raw signals for the in-situ recordings and the auralizations are also different, which further makes the comparison more difficult.

## 4. CONCLUSION

As part of the **CAHRISMA** project in-situ recordings of different signals have been made in some of the mosques and byzantine churches investigated. Furthermore computer models, using the ***Odeon*** software, have been made and from these auralizations have been calculated in

order to compare with in-situ recordings. When comparing the binaural in-situ recordings with the auralizations a good resemblance is heard both for the perceived reverberation, distance and the 3D experience. For the monaural in-situ recordings the 3D experience is lost, but still a good resemblance is heard for the perceived reverberation. This study shows that it is possible through auralizations to create or re-create a virtual 3D acoustical environment with good resemblance to the real world. Within the frame of the **CAHRISMA** project it will be possible to virtually create an acoustical environment in order for people to hear how an edifice "sounds", even though they physically are not present in the room. Furthermore it will be possible to re-create an acoustical environment, from historical data, in order to experience how an edifice "sounded" decennials ago.

## REFERENCES


1. Binaural in-situ recordings made in the ***Sokollu*** mosque and the ***Saint Irene*** byzantine church, by the Italian partners (from the University of Ferrara) in the CAHRISMA project. Monaural in-situ recordings made in the ***Süleymaniye*** mosque by the Turkish partners (from Yildiz Technical University).

2. Christoffer A. Weitze, Claus Lynge Christensen, Jens Holger Rindel and Anders Christian Gade. Computer Simulations of the Acoustics of Mosques and Byzantine Churches. 17th ICA, Rome, Italy, September 2 – 7, 2001.

3. Website link: http://helmholtz.oersted.dtu.dk/~caw/NAM.htm

   Link to website where examples of the in-situ recordings compared with simulated auralizations can be heard.