Application of an acoustic enhancement system for outdoor venues

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ABSTRACT- The implementation of an acoustic enhancement system has distinct benefits compared to traditional reinforcement systems. This paper outlines the application of an acoustic enhancement system for outdoor venues. As an example, the Tanglewood Music Shed, Lennox, Massachusetts, a well-known outdoor pavilion, is used as a fictitious setting for a SIAP enhancement system.

Introduction

The introduction of acoustic enhancement systems has given the acoustic consultant or acoustic designer more flexibility in creating multi-purpose environments. While some acoustical engineers may claim that these venues can only be designed with traditional sound reinforcement systems, some of the current state of the art enhancement systems can perform equally or better compared to those traditional systems. At the least, enhancement systems have their distinct advantages compared to the traditional reinforcement systems.

If the performance contains only electronic instruments, such as in a rock concert, then a traditional sound reinforcement system can be used. However, in outdoor pavilions there are many other types of performances, including drama, choral, chamber music, symphonic, jazz, etc., where the source is acoustic, as opposed to electronic. In these cases, enhancement is more appropriate than reinforcement.

Concept of the enhancement system

Most people are familiar with reinforcement, as a method of making a performance louder and improving coverage. The sound from each loudspeaker is a blended sum of all of the electronic inputs from the microphones or direct input instruments. Each loudspeaker is positioned, oriented and made appropriately loud to satisfy the requirements of the audience. In an enhancement system, the loudspeakers can more accurately be called “softspeakers”, because the sound from each one can not be heard individually. The predominate sound heard by the audience originates from the acoustic source on stage and the “softspeakers” simulate natural room reflections and reverberation. They essentially fill in the missing reflections in the room and are in effect providing electronic architecture. By appropriately delaying the sounds from these speakers, one can maintain the source of the performance as originating from the stage, thus creating the sensation that the listener is in an appropriately designed acoustical space for each performance.

For the implementation of an enhancement system for outdoor venues, it is important to understand the distinction between the two types of acoustic enhancement systems [5]. On the one hand, there are feedback based or non in-line systems, such as MCR, VRAS and CARMEN. These systems have a microphone section that picks up the reverberant sound energy of the hall itself, for recirculation through acoustic feedback. Therefore, these systems are dependent of the sound energy in the acoustical environment in order to apply some sort of enhancement. On the other hand, there are so-called in-line systems such as SIAP, LARES or ACS. These systems only pick up the direct sound energy from the stage and convolve the sound with electronically generated early reflections and reverberation. Therefore they can be independent of the reverberation of the hall.

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When an enhancement system is applied in an outdoor venue, it is obvious that there will be nothing like a natural reverberation to be picked up and fed back. Therefore, the non in-line systems cannot be applied and for outdoor purposes only the in-line systems are of interest.

As mentioned above, SIAP is one of these in-line systems that are able to provide acoustic enhancement for outdoor performances. Compared to the other systems, i.e. LARES and ACS, the application of a SIAP system has a few advantages [1]-[4]. For example, in the contemporary SIAP installations, no time variation is applied. As a result, there will not be any audible artefacts caused by phase modulation, whereby even a piano recital can be performed without any problems. Furthermore, each of the microphones picks up the entire stage area and all of the installed loudspeakers radiate early reflections and reverberation. There are no separated early reflections and reverberation loudspeakers such as, for example, in the ACS installations. When comparing a SIAP system to a regular LARES system, it is important to consider the number of uncorrelated reflection patterns, keeping in mind that an enhancement system simulates incoherent and uncorrelated natural reflections. A LARES processor is fed by 2 microphone input channels and has 8 output channels [6]. This results in 16 uncorrelated reflection patterns. Contrary to this, a regular small or medium sized SIAP system is fed by 4 microphone input channels and has 28 output channels, which results in at least 112 uncorrelated reflection patterns. This can be increased for a high end system to 4 (or even 8) microphone inputs and 56 output channels, thus 224 uncorrelated reflection patterns. As a result of the larger amount of uncorrelated reflections patterns, the reverberation will sound more natural without any kind of time variance.

Loudspeaker layout – fictitious implementation of an outdoor system

Besides the generation of a high quality reverberation, the type of loudspeakers and the loudspeaker distribution throughout the venue is also very important. One of the main concerns for the implementation of a SIAP system is the loudspeaker coverage. It is necessary that there will be enough frontal energy to cover the lack of early reflections in an outdoor venue, and enough lateral and medial energy to achieve enough envelopment. In order to explain the concept, a fictitious SIAP design in the Tanglewood Music Shed in Lennox, Massachusetts [7] is used to illustrate the implementation of such a system.

Frontal Energy

In small theatres, conventional loudspeakers with a frequency range of 50 to 10,000 Hz will be acceptable for the provision of early reflections. But in large fan shaped halls, such as the Tanglewood Music Shed, these kind of loudspeakers will not be able to provide enough frontal energy to the rear of the hall. Therefore, a lot of in-fill loudspeakers with appropriate delays have to be used. Besides the costs and the limited application of these loudspeakers, there will be delay differences and cross over effects that are difficult to overcome. As a result, in these situations SIAP has chosen to apply DSP controlled line-array loudspeakers [8]. Relative to traditional loudspeakers, these loudspeakers have the advantage that with a limited amount of loudspeakers the whole area can be covered with early reflections. Furthermore, the natural acoustics of the hall will be much less excited. This minimizes coloration by limiting disturbing reflections and controlling delay differences.

With respect to traditional (and modern, quite expensive) non-controlled line arrays, most commercially available DSP-controlled loudspeaker arrays provide enough sound power for enhancement purposes, while giving the added benefit of tightly controlled, frequency-independent directivity. A separate frontal system should be installed for the indoor and outdoor part of the venue. Figure 1 illustrates the frontal loudspeaker plan in both areas.

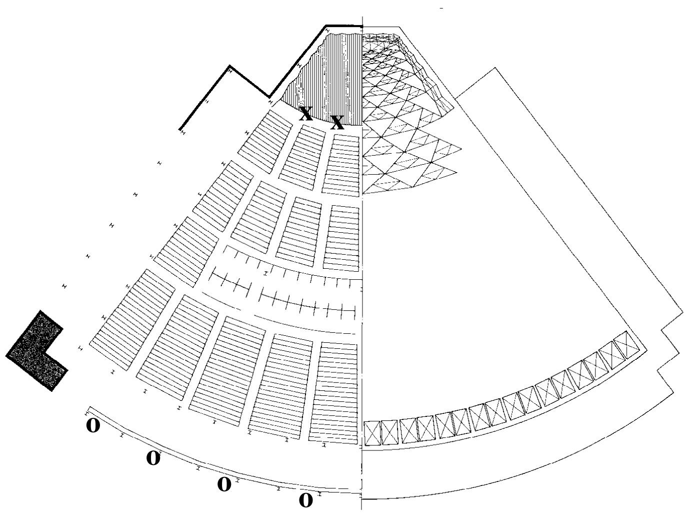

Figure 1: Concept of the loudspeaker layout for frontal energy for the left half of the Tanglewood Music Shed by application of DSP controlled loudspeaker arrays. The DSP arrays marked with X provide frontal energy to the inner half of the Music Shed, the DSP arrays marked with O provide frontal energy to the outdoor part. [Drawing from Beranek, 1962]

Lateral energy

The lateral energy is also important, because it is necessary to achieve an even coverage across the hall. In small halls, this can be achieved by application of conventional loudspeakers across the whole length of the sidewalls. However, for large fan shaped halls such as the Tanglewood Music Shed, including the outdoor part, it is almost impossible to obtain enough energy in the middle of the hall, without detecting the individual loudspeakers as lateral sources. According to the SIAP concept, there are two possible solutions to overcome these problems. On the one hand, it is possible to partition the hall into ‘subhalls’ with an average width of 30 m or less. Each subsection would have its own left and right lateral loudspeakers. This results in a more even coverage of the soundfield across the hall. In the figure below this concept is shown. It was successfully applied in two large acoustically dead arena halls for opera productions in The Netherlands (1990 and 1991).

Figure 2: Example of actual loudspeaker location during the Aïda opera in Amsterdam, The Netherlands. The arrow points at the loudspeakers that provide lateral energy for two different subsections.

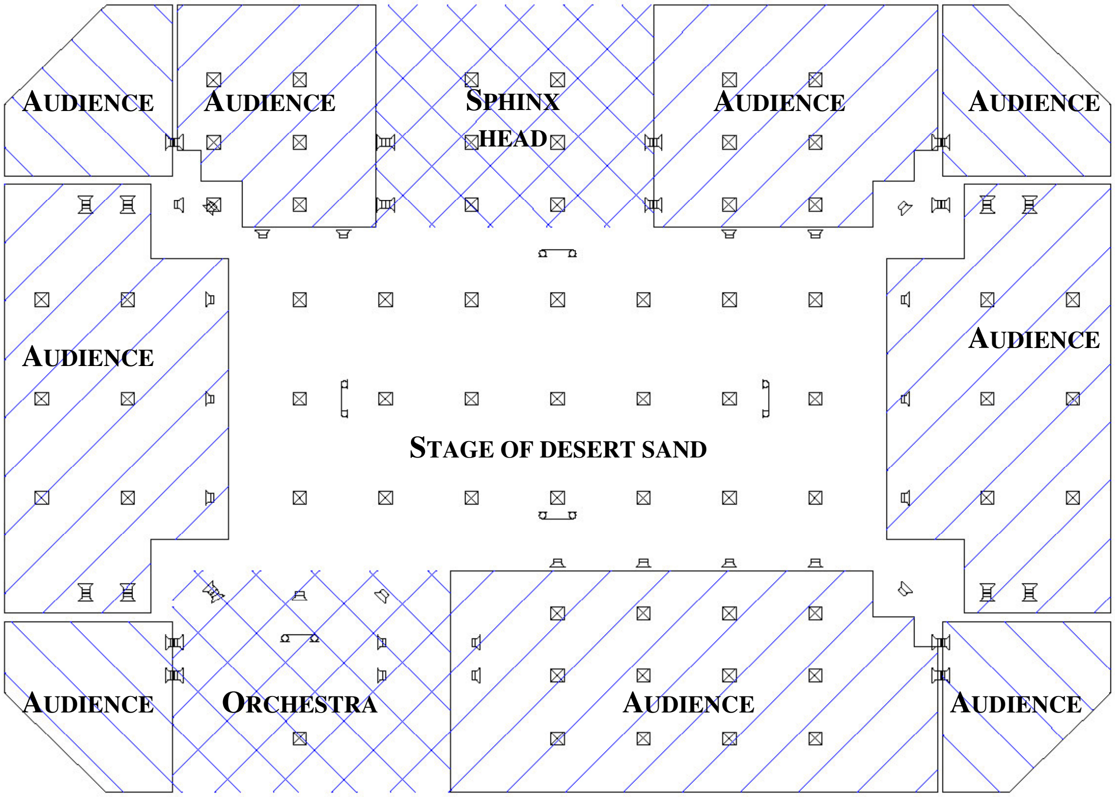

Figure 3 : Loudspeaker layout for Aïda opera production in Amsterdam, The Netherlands; 4,000 seats. The hatched parts present the subsections in which the hall was divided.

The concept of subsections results in a large amount of loudspeakers and amplifiers in the hall. Sometimes this can affect the architectural acceptance of an enhancement system. Therefore, if the budget for the system allows it and if the hall is large enough, advanced technology provides SIAP the tool to overcome these problems also by the application of DSP controlled loudspeaker arrays for lateral energy. As these arrays can be flush mounted in walls and a partitioning of the hall in subsections is not necessary anymore, this solution is in some cases more acceptable architecturally. The figure below shows the concept of the application of DSP controlled loudspeaker arrays for the lateral energy.

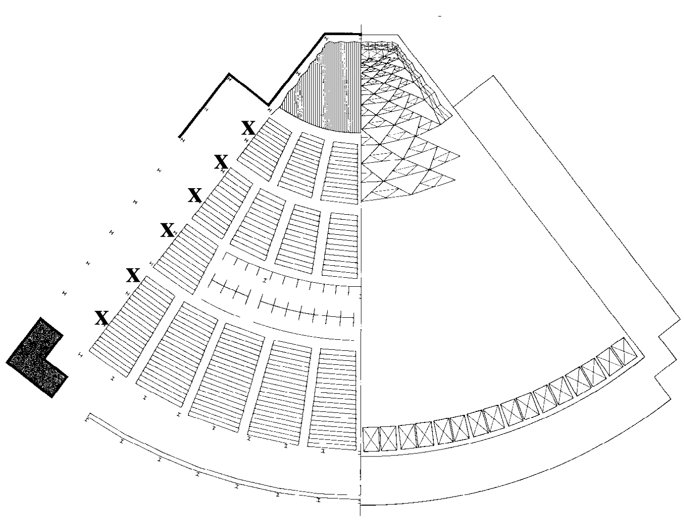

Figure 4: Concept of the loudspeaker layout for lateral energy for the left half of the Tanglewood Music Shed by application of DSP controlled loudspeaker arrays. The DSP arrays are marked with a X. [Drawing from Beranek, 1962]

Medial energy

Finally, we address the medial sound. As a rule of thumb, it can be said that each person should obtain sound from as many as possible, but at least three different, i.e. uncorrelated, medial loudspeakers. By increasing the height of the loudspeakers the effective coverage area, per loudspeaker, will increase proportionately as the square of the distance. The height of the roof in the Music Shed is limited, which implies an increase in the amount of loudspeakers to fulfil the rule of thumb.

Outdoors some other problems occur regarding the medial loudspeaker design. As there is no roof, there is no possibility for positioning of the medial loudspeakers, except with a complex rigging system. One way to overcome this problem is to create phantom sources. Theoretically this sounds like a nice solution, but practically there are a few problems with this concept. The loudspeakers that are used for the lateral energy, cannot be used for creation of phantom sources, because these loudspeakers have to be uncorrelated and are positioned much lower. A typical characteristic of the phantom source is that it is position dependent. Therefore, more loudspeakers should be used, which would be architecturally unacceptable and cost prohibitive. If the medial loudspeakers are located at the same height as the lateral loudspeakers, the dispersion of the phantom source will be too low. To overcome this problem the height of the loudspeakers could be increased, whereby the phantom source will have a dispersion that covers the whole audience area. It is obvious that this concept requires e.g. large poles and the resulting quality of the sound will be difficult to predict. Furthermore, the influences of time variant aspects, such as outdoor wind flows, are also difficult to predict. Therefore, this option is not very practical.

A more realistic option to achieve enough medial energy is to construct a frame across the audience area to which loudspeakers can be connected for the medial energy. However, this is also a very expensive concept and probably unacceptable from an architectural point of view. Therefore, the general thought is to omit the medial loudspeakers for outdoor enhancement. These will unnecessarily and significantly increase the cost of a system, without any certainty of the result.

Our experience with the SIAP system indicates that the application of a sufficient number of lateral loudspeakers, that are mounted preferably higher than normal, i.e. 3 m, can provide acceptable medial energy[2]. The application of DSP controlled loudspeaker arrays will be more difficult, because of their characteristic directivity. Therefore, the SIAP solution for outdoor medial energy is to divide the audience area in subsections and locate the loudspeakers high enough so there will be enough medial energy to achieve a high quality perception of envelopment.

Sound reinforcement versus acoustical enhancement

In order to make a theatre suited for multi-purpose performances, many consultants and designers are still sceptical towards enhancement systems and prefer the application of a traditional sound reinforcement system. The main problem of traditional reinforcement systems is that they are not flexible enough to be used for multi-purpose venues. As they do not add spaciousness and envelopment to the performance, the traditional reinforcement systems have their shortcomings, especially in those situations where additional acoustic enhancement is also necessary.

To address both acoustical (drama, choirs, string ensembles, symphonic orchestras, etc.) and amplified performances (rock concerts) properly, two types of enhancement systems can be distinguished. On the one hand, it is possible to implement the enhancement system as a separate addition to a reinforcement system. On the other hand, the enhancement system can be combined with the reinforcement system, thus performing both functions as required. Both concepts will be explained in more detail.

When the enhancement system is implemented as an addition to the reinforcement system, the reinforcement system has a separate loudspeaker configuration. The reinforcement system is only assisted by the enhancement system's loudspeakers with regards to surround sound or under balconies, for example. This way of implementing an enhancement system enables the reinforcement engineers

[2] Dependent on the width of the audience area, the location of the lateral loudspeakers can be much higher relative to the normal indoor installations

to implement their system of choice for the reinforcement. The disadvantage is that for both enhancement and reinforcement separate frontal sound systems will be employed, which of course will be more expensive.

Instead of applying the enhancement system as an addition to the reinforcement system, the enhancement system can also be expanded to perform as the reinforcement system itself, as well as providing the enhancement.
This way of using the enhancement system has the advantage that the frontal energy loudspeakers for the enhancement and reinforcement can be combined in one system. Another advantage is that with one push on a button both enhancement and reinforcement systems can be configured at once (ease of use). The main potential problem with this approach is that the reinforcement engineers have to accept the choice of the enhancement systems loudspeakers for their use. If predominately reinforced performances are envisioned, the choice of the engineers may be of overriding importance.

Both concepts can result in a truly flexible system, giving added quality to both acoustical and electrified performances. Additional applications possible with the implementation of an enhancement system are, for example, acoustic, spatial and envelopment enhancement, theatre and music reinforcement, theatre and movie surround sound, and in-fill reinforcement for partly concealed areas (over and under balconies).

Conclusion
Sometimes a trade off has to be made in selecting either a traditional reinforcement system or an acoustical enhancement system. Modern enhancement systems have several advantages over the traditional reinforcement systems, when acoustic performances form an important part of the events presented in the venue. When the audience area is very large, a (well-designed) sound reinforcement system is unavoidable to support the direct sound with as much natural sound qualities as is reasonably possible. The optimum situation, however, is obtained when the acoustic enhancement and reinforcement system are combined. One of the advantages of such a combination is that a significant part of the required sound energy is provided by the enhancement system, which results in a better overall sound quality. As a result the main concern is the type of loudspeakers which are used to achieve the most acceptance of the system.

The application of an enhancement system for outdoor venues has some typical problems. First of all the concept of the system is important, i.e. the system has to be a so-called in-line system, which is not feedback based. As described SIAP has a few advantages in its application compared to other systems. Besides the concept of the system itself, the loudspeaker layout is also very important. The Tanglewood Music Shed was used to illustrate the implementation of a SIAP system and to explain the concepts for a proper loudspeaker layout to deliver the appropriate frontal, lateral and medial sound.

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