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2aAAa1. Electronically variable room acoustics - motivations and challenges

K. Anthony Hoover* and Steve Ellison

***Corresponding author's address: McKay Conant Hoover, 5655 Lindero Canyon Road, Westlake Village, CA 91362, thoover@mchinc.com**

Electronically variable room acoustics, or 'active acoustics', has become an effective solution to a variety of room acoustics challenges. The motivations for considering such systems often go beyond acoustics. Energy conservation, financial considerations, historic preservation, and balancing the needs of a venue's constituencies all can play a role in the determination to employ active acoustics. This paper will discuss some practical examples, including planned renovations to the Santa Monica Civic Auditorium, home of the Academy Awards during the 1960s, a resident orchestra, legendary rock concerts, and a unique hydraulic floor to convert the Civic from a performance space to an exhibit space. The active acoustic system objectives, design strategies, and challenges will be discussed.

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INTRODUCTION

Performing arts venues and musical arts organizations such as symphony orchestras face continued pressures to succeed under challenging economic conditions. Orchestras face ever-growing expenses and declines in some types of performance revenues. [1] In many cases, an orchestra cannot support a purpose-built performance venue, and must utilize a venue such as an auditorium or theater that has less than ideal acoustics in which to perform.

Among the many parameters for proper acoustical environments are the reverberation times, which vary with frequency, and are directly related to the volume of a space and inversely proportional to total sound absorption. Moreover, the preferred reverberation times vary with the type of performance; generally, performances emphasizing speech and amplification prefer reverberation times that are considerably shorter than for unamplified music, and there is a range of generally-preferred reverberation times for various music styles. Table 1 shows mid-frequency reverberation time goals depending on musical style and are also somewhat dependent on room volume and seating capacity. [2,3,4,5,6]

TABLE 1. General goals for mid-frequency reverberation times.

Music Style	T60 Goals (seconds), mid-frequencies
Organ, Choral	2.1 – 4.2
Baroque	1.3 – 1.5
Early Classical	1.6 – 1.8
Romantic Classical	1.8 – 2.2
Later 20th Century	1.4 – 2.0
Amplified Music	0.5 – 1.2 (added concerns for bass)
Drama Theatre	0.7 – 1.1
Cinema	0.4 –1.0

Very often, performance venues must be able to present a range of musical performance types, in turn suggesting that the reverberation times be varied to optimize the musical style. Furthermore, speech intelligibility and amplified music require that reverberation times be minimized as best possible. Reverberation variation may be accomplished by changing the volume and/or the total sound absorption in the space using variable physical architecture such as curtains and physically coupled reverberation chambers.

Variability provided by active acoustic systems represents a viable option. Technology has evolved considerably since the first systems were installed in the early 60's, [7] and carefully designed systems using quality components provide acoustical flexibility [8] and can be well integrated with the venue's interior. Further, it has been shown that active acoustics systems are an environmentally sensitive option. [9]

These systems depend on the venue having an initial reverberation time that is the shortest desired for an activity in the space, since they can only add or extend reverberation times. Thus, the design often starts with providing permanent sound-absorptive treatments.

AN EXAMPLE – SANTA MONICA CIVIC AUDITORIUM

The Santa Monica Civic Auditorium (Santa Monica, CA) hosts a wide range of programming. It was home of the Academy Awards during the 1960s, and has supported a resident orchestra, pop shows, theater, legendary rock concerts, and features a unique hydraulic floor which is still in use since the opening in 1958 to convert the Civic from a performance space to an exhibit space.

Average house ceiling height is approximately 10.5m, which is too short to develop quality reverberation. The front of the existing wall is sound reflective, intended to promote projection from stage into the audience, but the orientation is highly ineffective. Furthermore, the average house width is 42m, which is too wide for desirable side reflections. The house length is 45.5m. Seating for full concert functions is up to 3,000; banquet functions with round tables on the main floor can accommodate up to 720 seats.

For very general reference, Boston Symphony Hall, one of the world's finest concert halls, is a classic "shoebox" design, whose house is 18.5m high, 23m wide, and 38m long. Overall, the Santa Monica Civic Auditorium space is too short and wide for desirable orchestral concert acoustics, complicated by poor shaping, so it would be very difficult to renovate the space to provide a quality reverberant character and desirable acoustical environment. Therefore, it was determined to increase the absorptive treatment, and design an active acoustic system for this space using the commercially available Constellation Active Acoustic system, which utilizes VRAS algorithms. [10]

The average existing reverberation time is 2.1 sec @ 1,000 Hz, as measured in the unoccupied space (set for exhibition function, with carpet on the main floor and with main floor seating removed). The goal was to reduce the reverberation time to 1.2 seconds (all seating in place, but no carpeting), by addition of permanent sound absorptive treatment on the side walls, which would be highly beneficial for rock concerts and amplified music performances, and would serve as a good foundation for active acoustics.

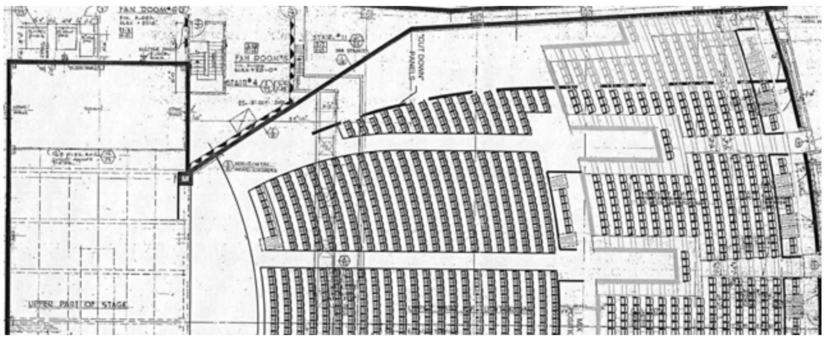

FIGURE 1. Half of floor plan, stage and seating area, Santa Monica Civic Auditorium

Figure 1 shows half of the floor plan (which is symmetrical), with stage house to the left and audience area to the right. Note the highly splayed front wall (finished mostly with sound-reflective metal panels), the flat wall from the end of the splayed wall to the rear wall (finished mostly with sound-absorptive perforated-metal panels), the curved real wall (finished mostly with sound-absorptive perforated-metal panels), and cross aisle at mid house.

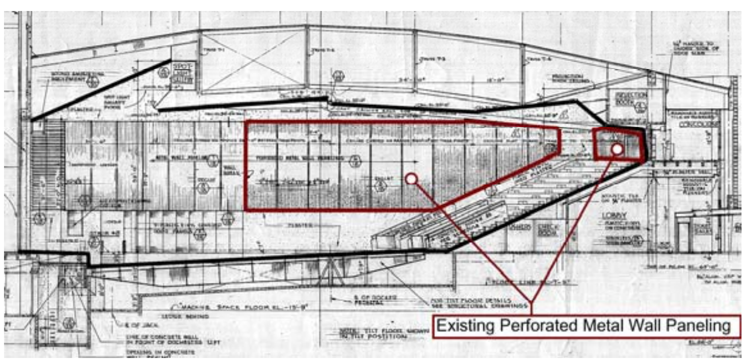

FIGURE 2 (A). Longitudinal section, existing absorption (perforated metal wall paneling)

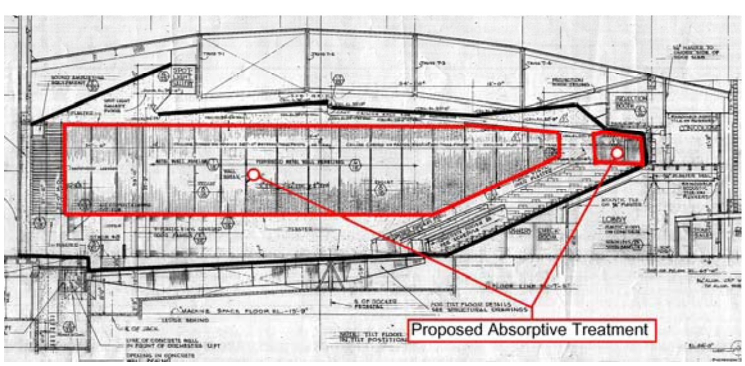

FIGURE 2 (B). Longitudinal section, proposed absorptive treatment (extended overall treatment)

Figure 2A shows the existing sound-absorptive treatment, which extends from the end of the splayed wall throughout the rear of the wall surfaces. The outlines of the ceiling (heavy plaster) and floor surfaces are bolded for clarity. Note the section of floor that is forward of the raked seating; this section is a single large floor that can be tilted by a hydraulic system, primarily to convert from performance to exhibit functions. Figure 2B shows proposed absorptive treatment, extending the overall treatment to include the splayed wall sections.

ACTIVE ACOUSTIC SYSTEM DESIGN CONSIDERATIONS

Active acoustics can be applied to both the stage area as well as the house. A stage system will enable musicians to hear each other better and capture energy that is useful for energizing the house. While both stage and house systems can be operated independently to some degree, they are typically part of an overall integrated system.

Stage System

Stage systems can provide flexible conditions for musical performers by providing control over early and late energy strength, reverberation time, early reflection density, and frequency response. Microphones placed over the stage receive energy from the musicians, and signal processors generate acoustical signals that are delivered to the musicians from loudspeakers that are placed both laterally and overhead. Further, the early energy captured onstage by such a system can be used to generate early reflections to the house, and increase the sense of intimacy and presence between the audience and the performers. The system response is full range, and transducer density is set so that musicians do not localize to individual loudspeakers. Materials such as scrim can be used to hide the loudspeakers, and sometimes loudspeakers may be integrated with physical architecture, such as sidewalls. If a fly space is available, components can be easily deployed and retracted without requiring the amount of storage needed for a physical orchestral shell.

The conditions desired by symphony orchestras, chamber groups, and vocal ensembles such as choirs are quite different. Unique acoustic presets may be created for each ensemble. Dammurud et.al. suggest that "for future investigations of the relationships between physical objective conditions and perceived conditions among the musicians, it appears essential to not be limited to quantitative studies only and that realistic and relevant physical (acoustic) conditions are studied. The results from the three- year project suggest that the presence of the orchestra on stage is important when considering acoustic conditions and that a lot of factors which are not easily quantifiable are highly relevant for perceived conditions." [11] A benefit of an electronic stage system is that the acoustic parameters can be varied easily during the tuning process with the orchestra present and providing their collective input regarding their acoustic experience.

An active acoustic shell at the Santa Monica Civic Auditorium would be easily stored using dedicated pipe battens. Three or four pipes would be required, depending on the footprint of the orchestra. If such a system is not used and a physical shell is employed, then microphone positions need to be coordinated amongst the overhead shell elements.

House System

Active acoustic systems need to provide acoustic energy in the house seating area from all directions, as would be expected of physical architecture. Loudspeakers must be selected and arranged such that they provide full bandwidth energy, are integrated with the physical architecture, and are of sufficient numbers to provide sufficient independent (de-correlated) modes and minimize the risk of localization to an individual loudspeaker. If they are also used for program audio such as surround sound signals, then their ability to deliver sufficient SPL for direct coverage may drive the decision to use more powerful components. Microphone positions are selected over the house seating to maximize their distance from loudspeakers, provide sufficient quantities for regenerative power gain, and sufficient coverage so that all room sources excite the reverberant field in a similar fashion as physical architecture. Multiple reverberation processors are used to increase reverberant power gain potential and minimize the time it takes for sound sources throughout the house to excite the reverberant field.

The room's reverberation radius is used to both determine loudspeaker – microphone spacing as well as guide the spacing of loudspeakers to avoid localization. After acoustic treatment, the Santa Monica Civic Auditorium's reverberation radius will be approximately 7.5m. Therefore, if loudspeakers within coverage of the listener are closer than this distance, a higher density is used for sufficient overlapping coverage.

In the Auditorium's active acoustic system design, 38 overhead loudspeaker positions are distributed above the seats where the listener to ceiling height exceeds 7m. Overhead positions are of a higher density in the rear of the seating area due to the closer distance from listeners to the ceiling. Sidewall locations are selected that are approximately 4m above the finished floor, and spaced every 3m. Rear lateral loudspeaker positions are lower and at a higher density due to their proximity to listeners. For those seated in the center of the room, much of the lateral energy received will be from overhead loudspeakers on either side of the venue. Early reflections generated by the active acoustic system to the lateral and overhead locations will increase the sense of intimacy and presence, particularly in a venue with this width. [12]

FURTHER CONSIDERATIONS

The decision to utilize an active acoustic system is driven by a desire for flexible, high quality highly variable acoustics as well as other venue and tenant concerns. These typically include cost, interior design integration of the elements, projected range of events to attract to the venue, and environmental concerns. The process of making this decision involves bringing all the constituencies involved together, including architect, general contractor, venue owner, and musical organization representatives. Often, this process is as demanding and time consuming as the design itself. Coordination of the final design must be made with HVAC, lighting, plumbing, and electrical engineers. However, the result of such an effort can be a venue that more than lives up to the moniker "multi-purpose."

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