Theatre sound system enhances music experience

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by John Matheson

LARES: What people said...

Through the 1980s and 1990s there has been an unprecedented advancement of computer and digital signal processing (DSP) technology. Spawned by the introduction of personal computers and the compact disk, the electronic tools now exist to recreate the quality of real acoustic spaces, to create virtual rooms if you like.

Acoustical engineers traditionally control the acoustics of spaces by adjusting the properties of boundary surfaces. To the extent that architects and interior designers will allow them, they control the sizes, angles, and absorptive and reflective properties of the walls and other surfaces in a space.

The 2000 seat Adelaide Festival Theatre auditorium's new electro-acoustic system greatly enhances the musical experience of the audience.

On a small scale, DSP has been used to create concert hall or ambience effects for home stereo and theatre systems and even in car entertainment systems. Now large-scale electronic architecture systems are being installed in public venues such as drama playhouses, opera houses and concert halls, both as remedial acoustical treatment for existing under-performing venues and in new multipurpose venues to allow for variable acoustics to suit different performance styles.

Electronic architecture does not eliminate the need for good architectural acoustical design, but its application is very flexible and it can be used to overcome some of the physical limitations of traditional architectural acoustics.

The desirable acoustical behaviour of a performance space depends very much upon the type of performance presented in that space. For example, there are fundamentally different acoustic requirements for speech, amplified performances, opera and orchestra.

The spoken word needs strong early frontal reflections to give adequate strength (ie loudness) to be heard, an absence of echoes and a short reverberation time to prevent loss of articulation. Similarly, amplified performances need a freedom from echoes and a short reverberation time.

Symphony orchestra concerts need a longer reverberation time to blend the sounds from each part of the orchestra, with strong lateral, rather than frontal, reflections to create a sense of envelopment and spaciousness. Because early composers were constrained by the performance spaces available to them, they wrote music to sound good in those spaces. Thus music from the baroque period is best performed in small auditoria, classical music in larger auditoria and late romantic music in very large auditoria.

Concert hall reverberation would, however, impair articulation of the human voice in an opera performance. Opera, like speech, needs strong early frontal reflections for the voices to be audible, but also needs the auditorium to blend orchestral sound from the pit harmoniously without overpowering the singers. The reverberation time required for opera is a compromise between orchestra (long) and speech (short).

Electronic architecture is the creation of acoustic fields to alter the acoustic behaviour of a space. The aim of electronic architecture is to provide improved acoustics in existing venues and variable or virtual acoustics in general. These systems work by electronically placing virtual reflecting surfaces in desirable positions, and by electronically removing excess sound absorption.

Electronic architecture has nothing in common with public address systems other than it is achieved through the use of sound equipment, that is microphones, signal processing, amplifiers and loudspeakers. In contrast to conventional sound reproduction systems, sound systems for electronic architecture are generally characterised by having a small number of microphones and a very large number of loudspeakers which "tile" the walls and ceiling of a space.

These systems have some stringent requirements setting them apart from conventional public address design approaches. Electronic architecture is generally used to "amplify" the acoustical space, rather than the performers, in the same way that walls and reflectors would, if the acoustical engineer had the freedom to place them where they are needed. The resulting musical balance is not determined by a sound engineer, but left firmly in the hands of the conductor or musical director.

The development of electronic architecture started in the 1930s with experiments conducted by RCA at the Philadelphia Academy of Music where stairwells adjoining the auditorium were excited by loudspeakers to increase the reverberant energy level in the hall. In 1955 the first Philips Ambiophonics system was installed in the La Scala Opera House in Milan, Italy.

This was followed by the AR (assisted resonance) system installed into the Royal Festival Hall, London, then came MCR (multichannel reverberation), ERES (early reflected energy system), RODS (reverberation on demand) and ACS (acoustic control system).

Several companies are currently marketing electronic architecture systems using modern DSP techniques, including the European SIAP (system for improved acoustic performance), American LARES (lexicon acoustic reinforcement & enhancement system) and Japanese Yamaha AFC (acoustic field control).

When it was decided to stage the Paris Théatre du Châtelet's version of the entire Der Ring des Nibelungen, Wagner's epic cycle of operas, in the Adelaide Festival Theatre, there was a great deal of concern that the much maligned acoustics of the theatre would not please high ticket price paying patrons (around $1000 each). Acoustical refurbishment of the theatre was considered paramount.

The Festival Theatre auditorium's acoustics provided good, even coverage for speech, contemporary music concerts and musicals. The reverberation time was long at low frequencies, short at middle frequencies and very short at high frequencies for the auditorium's size. Low frequency resonance sometimes caused problems for sound engineers.

When the theatre opened in 1973, it was regarded as an acoustically innovative design for its system of retractable acoustic curtains along the rear walls and a false ceiling above. The design of the ceiling was intended to promote reflections back to the auditorium, while still being open enough to allow the development of reverberant energy in the volume above that could filter back down to the auditorium.

After being in operation for some time, the theatre came to be regarded as having less than satisfactory acoustics for symphony orchestras, and to a lesser extent opera, primarily because of its excessively short, middle and high frequency reverberation time.

The walls of the theatre are covered with decorative wooden blocks, which are a hardwood tile varying in size, but typically 200mm square and 50mm deep. The builder, without authorisation from the acoustical consultant, incorporated a gap between each tile. The gap was intended to prevent the tiles from dislodging from the wall should they expand as a result of absorbing moisture. The main reason why the auditorium did not perform as expected was a result of the air gaps (varying between 40mm and 65mm in depth) acting as frequency selective (quarter wave) absorbers.

The remedial acoustical objectives were:

- to improve the theatre's performance as an opera house
- to improve the theatre's performance as a concert hall, without diminishing its performance as an opera house
- to improve the natural acoustic fold-back to on-stage performers
- to improve some low frequency problems affecting sound reinforced productions.

The proposals considered architectural methods of:

- improving the early-reflected energy to those seats not shielded under balconies by reshaping the side walls and preferably reshaping some ceiling elements
- increasing loudness by closing the horizontal sections of the ceiling
- increasing the coupling between the auditorium and the above ceiling volume by removing significant areas of the nonhorizontal sections of the ceiling
- increasing the reverberation time in the middle and upper frequencies by removing the side wall wooden blocks (or caulking to overcome their existing absorptive properties)
- increasing fold-back to stage by reshaping side walls, providing suitable diffusing elements on the side walls, shaping ceiling and proscenium reflectors to suit this purpose and providing a solid reflector at the orchestra pit rail.

Overcoming other specific problems including the provision of diffusive elements on the auditorium rear walls, diffusive elements to the orchestra pit, and additional low frequency absorption to specific areas in the stage tower and above the auditorium ceiling. The proposed changes would have taken significant time and money and required relatively long-term closure of the theatre. Preliminary estimates of cost ranged from $5 million to 10 million, excluding the loss of revenue caused by closure of the theatre.

The acoustic environment under the balconies would still have been less than acceptable for opera and orchestra and some form of future electronic system would still be needed to assist in improving the acoustics under the balconies in particular. At the same time, it was important to retain or enhance the theatre's suitability for both amplified music and orchestral concerts. No architectural acoustical solution could meet these divergent requirements.

Reports in professional literature pointed to recent developments in electro-acoustical technology and its increasing application in the United States and Europe for either improving poor acoustics in existing auditoria or providing adjustable acoustics for new auditoria.

The use of a fully developed electro-acoustical system appeared not only to be able to significantly improve the sound fields under the balconies, but also had the ability to provide an appropriate sound field that emulated the acoustical effects that were being sought by the various architectural changes. It was important that such a system was transparent in its operation, that is, was not discernible in its normal use.

Further investigations were undertaken to determine:

- if currently available systems were transparent in their operation
- if so, which of the two most likely systems available (SIAP or LARES) was preferred
- it was also important to determine if the major users of the theatre would accept the concept of such a system as there was no point in proceeding along this approach if there was strong resistance to the use of an electro-acoustic system.

There was qualified interest before the investigation and positive support from both State Opera and the Adelaide Symphony Orchestra given the findings of the investigation.

The benefits of implementing a suitable electro-acoustical system were:

- the architectural changes required to increase the early nonfrontal energy required to the majority of the seats were eliminated and the amount of diffusive elements significantly reduced
- the acoustical deficiencies under the balconies were addressed affording improvements to the sound field; this is not practical using a purely architectural solution
- the provision of early energy "foldback" to the stage eliminated the need for architectural work around the proscenium and for diffusing elements on the sidewalls and ceiling.

Stephen Phillips (general director, State Opera of SA), Dr Peter Swift (principal acoustics engineer, Bassett Acoustics) and I (at the time logistics manager for the Festival Centre), formed an evaluation team. The method of evaluation consisted of visiting and auditioning venues with systems installed using live performances by singers and musicians as the test signal, and talking to the music industry professionals who use these venues.

Major performing arts venues visited included:

- Brooklyn Academy of Music - New York (LARES)
- Vivian Beaumont Theatre at the Lincoln Center - New York (SIAP)
- Hummingbird (formerly O'Keith) Centre - Toronto (LARES)
- Olivier Theatre at the Royal National Theatre - London (SIAP)
- Muziektheater - Amsterdam (LARES)
- Chassé Theater - Breda, The Netherlands (SIAP)
- Deutsche Staatsoper - Berlin (LARES)
- Koninklijke Nederlandse Schouwburg - Antwerp, Belgium (SIAP).

A LARES system was chosen because it gave, in the evaluation team's opinion, a superior musical experience. Some passive acoustic changes were also incorporated. The carpet was replaced with parquet partly to extend high frequency reverberation, but also to appease people who thought carpet and good acoustics don't go together.

Absorptive treatment to the fly tower above the stage and the ceiling space above the auditorium reduced low frequency reverberation, giving more even reverberation times across the frequency spectrum. A modified orchestra pit rail was constructed and rear wall absorption was installed to reduce an echo problem.

LARES Associates do not provide "turnkey" installations, or even complete system designs. They manufacture and supply key components, such as the acoustic DSP processors, and provide design criteria such as loudspeaker placement recommendations. They work in partnership with acoustic consultants and specialist sound designers on each project.

The Festival Theatre system design was a collaboration between Steve Barbar (principal, LARES Associates), Swift, and myself. E-mail was used extensively to ferry documentation back and forth between parties. Barber at LARES in Boston, US, worked from three-dimensional AutoCad drawings, photographs and a textual description of the space.

LARES Associates allowed considerable freedom in the specification of the system peripheral equipment. The design team chose to implement the system using Peavey Media Matrix, which is a PC based virtual sound system. The advantage of this approach was a great reduction in the amount of physical equipment that needed to be installed, and complete flexibility to redesign the system without a physical rewire.

A Crestron computer control system was used to adjust each piece of equipment according to the room setting chosen. Crestron is a dedicated control system that commands any other controllable device, whatever it is, via a dedicated Cresnet data network and suitable interfaces. The heart of the Crestron controller is a colour touch screen computer display panel. On this panel the appropriate setting for the LARES system is selected for each performance. The panel incorporates password security to prevent tampering and limit control options. Because of the Crestron control system no special skills are required to operate the LARES system.

The team decided to pursue the manufacture of loudspeakers in Adelaide, since it has long been a centre of excellence for loudspeaker design being the home town to some of the world's best HiFi audiophile manufacturers, namely Krix Loudspeakers, VAF Research, Sonique Sound Technology and Duntech Audio.
Krix and VAF were invited to build prototype loudspeakers, which were air freighted to Boston for evaluation. Both were rated as superior to the LARES benchmark, and ultimately the VAF version was chosen for installation by competitive tender. In the Festival Theatre system 287 loudspeakers were installed.

A new Australian Monitor amplifier was developed based on the well-known AM1200 workhorse with an on-board microprocessor and in-built Cresnet computer network interface for control and monitoring. The 51 amplifiers are conservatively rated at 4 x 200W each for a total system power of more than 40,000W.

John Matheson holding one of the specially developed VAF Research loudspeakers. Racks of Australian Monitor amplifiers are in the background

The installed cost of the system amounted to $850,000. The whole project from design to installation took just under five months from state government go-ahead, to be completed in time for initial system tuning in September 1998. Within this time frame, the loudspeaker and amplifier prototypes were developed and evaluated prior to manufacture and installation.

In all, there were nearly 100 speaker penetrations in 200mm poured concrete wall or ceiling slabs and 56 in 100mm concrete, all of which had to be air tight and sound proof. After taking five weeks to chip out 28 side wall holes with circular saws and jackhammers, the contractor brought in a concrete cutting chainsaw complete with diamond embedded chain. The other side wall took less than one week.

Each loudspeaker is individually connected with inductance cancelling cable to the racks of power amplifiers mounted with the LARES equipment in a room at the rear of the second balcony. This location was chosen to minimise the length of loudspeaker cabling, which still runs to nearly 20km. The amplifiers and processing equipment dissipates about 15kW quiescent, necessitating airconditioning for the equipment room.

Operation

There has been very strong positive acclaim by patrons, critics and performers. The improvement in sound is theatre wide but in particular under the balconies at the rear. When the LARES system is operating it is not obvious that it is doing anything or that anything is happening. Even when standing quite close to a loudspeaker, no sound is readily apparent from it.

However, for the audience, opera singers are louder and have great clarity. The orchestra is warmer and well blended. In concert mode there is a greater sense of envelopment. Sitting in the rear of the stalls or first balcony under the balcony overhang above, you can close your eyes and imagine that the low ceiling has gone and that you are in the middle of a great concert hall.

The listeners feel like they are in the same acoustic space as the performers because the microphones pick up ambient audience noise as well. Performers hear the auditorium in a way that supports their performance. Singers and orchestras are able to hear each other much more clearly, greatly assisting ensemble work.

People sense these changes but do not attribute them to the electro-acoustic enhancement. Most people, including music professionals, can only believe what the system is doing by having it disabled during use.

The following published reviews typify the success of this installation.

"Generally the sound is a miracle, every harp glissando and thundering percussion glittering like electricity in the theatre's new acoustic." Noel Purdon reviewing The Ring operas in RealTime, February - March 1999.

"Thankfully, the disagreeable old acoustic has at last been banished. In its place on this occasion there was considerably increased volume and resonance coupled with freshness and even some

edginess to the sound." Rodney Smith reviewing the first Mozart symphony concert in The Advertiser, 12 April 1999.

Electronic architecture through electro- acoustic systems has given us the ability to create virtual acoustic spaces. To date, most electronic architecture systems have been retrofitted to improve the acoustical performance of existing venues, with the bonus that electro-acoustic systems bring the potential for variable acoustics.

New multipurpose auditoria designed from the ground up with electro-acoustic systems will benefit from relaxed constraints on some acoustical requirements difficult to achieve through architectural design.

In the past, composers were constrained by the performance spaces available to them and wrote compositions to suit those spaces. It is probable that contemporary composers will write works to be performed in variable acoustics.

Electronic architecture has broad application and we will see its use in:

- sports stadiums to boost crowd excitement levels, which is crucial during early season matches when crowd numbers are low
- churches to boost congregational responses and ensure a sense of involvement
- professional and music school rehearsal studios to let performers hear what it will sound like when they perform on stage in any acoustic space from a Baroque hall to the Boston Symphony Hall or Saint Paul's Cathedral.
- Outdoor fine music performances - electro-acoustic systems can provide the early energy and reverberation that would be present in a concert hall or opera house.

*At the time of writing, **John Matheson** worked for Bassett Acoustics, an independent firm of consulting engineers, as an electro-acoustic designer. Before joining Bassett Acoustics, he worked for many years at the Adelaide Festival Theatre where he held the positions of theatre logistics manager and technical manager - sound. John is currently employed by VAF Research.*