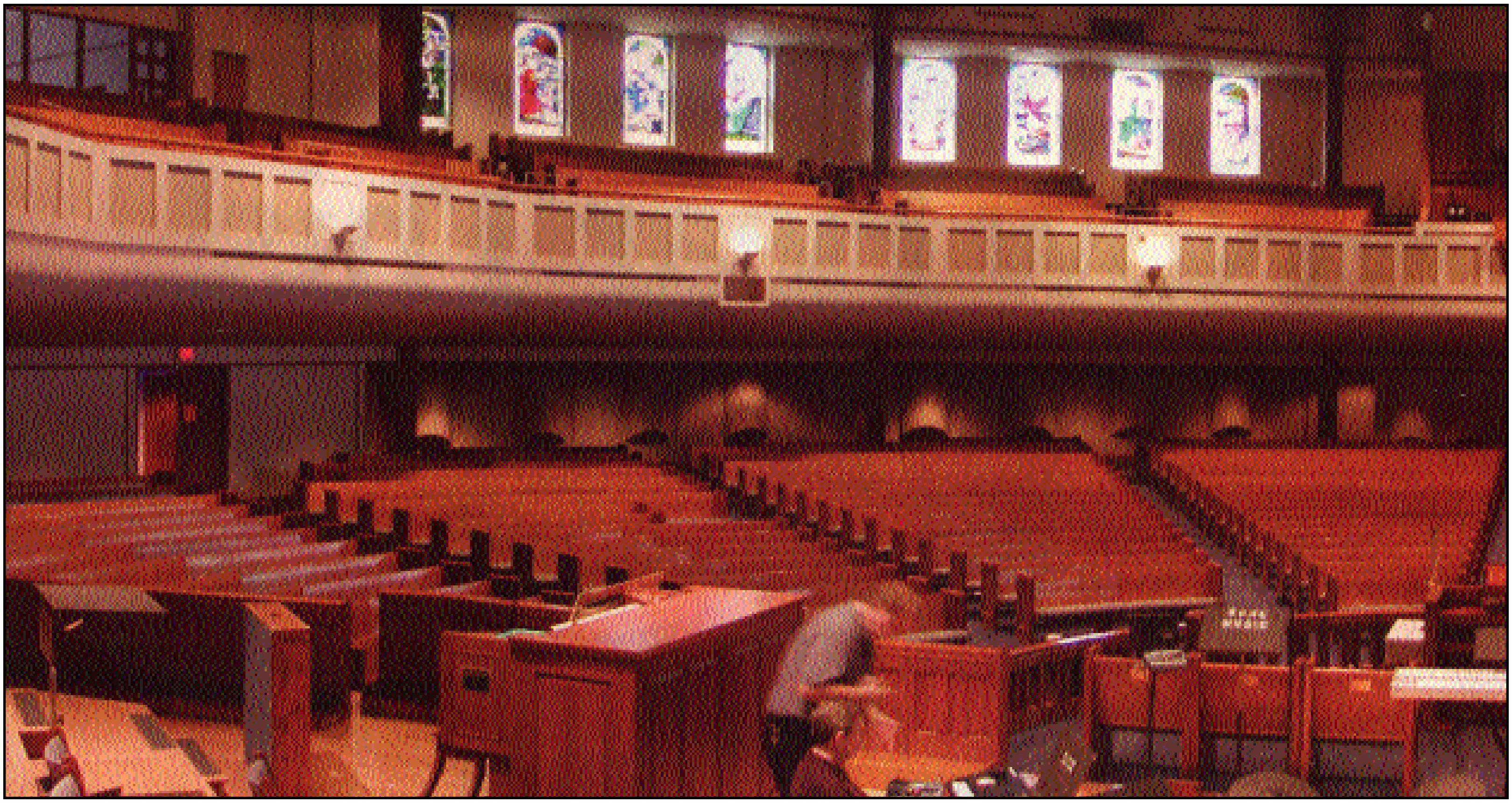


ACOUSTIC ENHANCEMENT SYSTEMS IN HOUSES OF WORSHIP

Solving problems in these difficult structural environments.

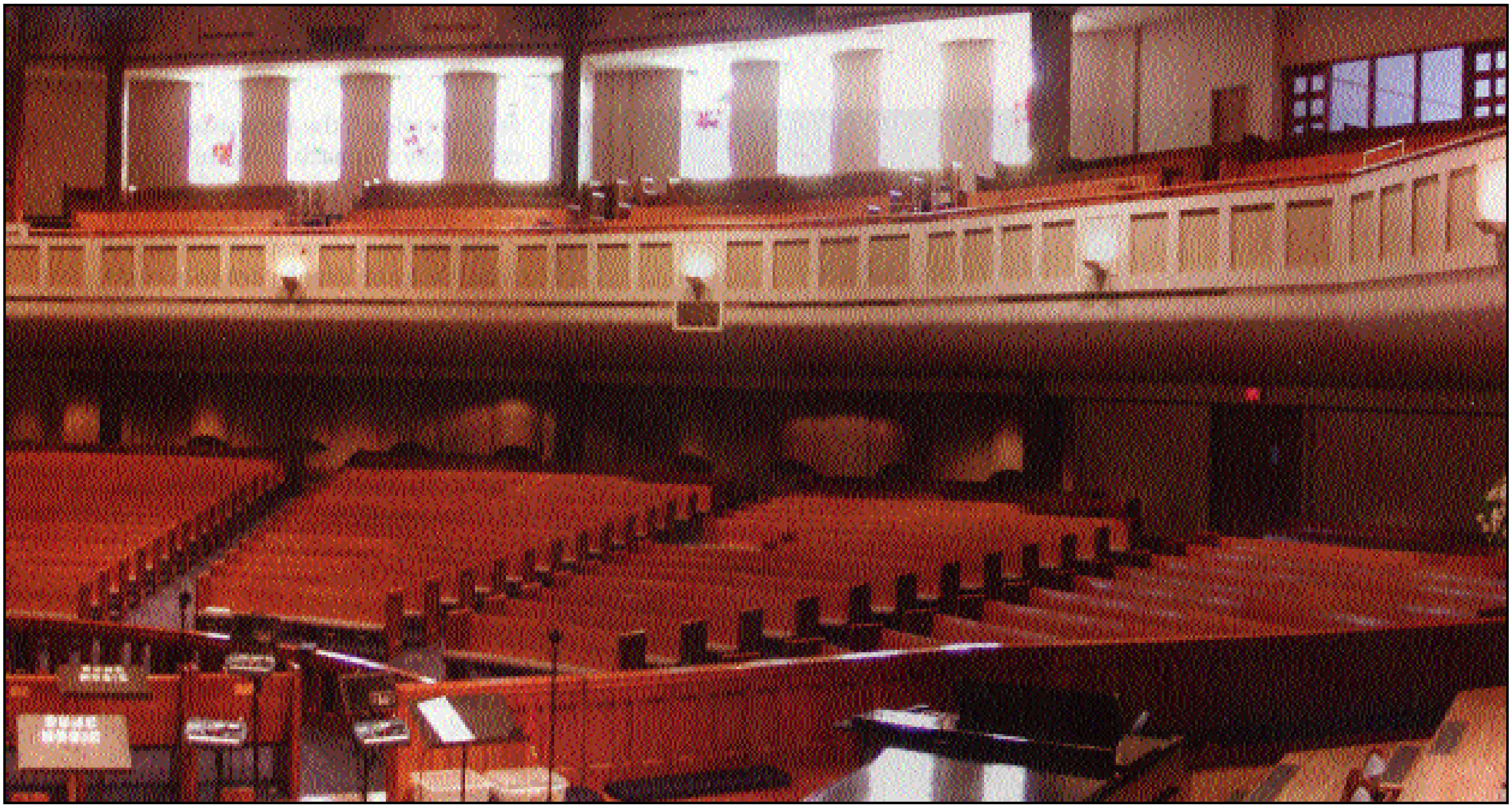
BY DAVID MCNUTT

The problems associated with designing a venue that has good acoustics for speech are well understood. Minimizing strong reflections and lowering reverberation time and level produces greater overall speech intelligibility. The enveloping reflected field and the reverberation that is vital to the listening experience for acoustic musical sources, such as an orchestra or choir, are often a hindrance in designing sound systems for intelligible speech. Nonetheless, electronic sound systems designed to increase speech intelligibility in both dry and reverberant spaces have been used for some time, with largely successful results.

Conflicting Requirements

But often a venue must accommodate performances with conflicting acoustical requirements, such as music and drama, which make designing the venue even more problematic. Under these circumstances, optimum acoustics for varying applications are nearly impossible to achieve using traditional architectural treatments. As a result, we have seen a rise in the use of electronic acoustic enhancement systems. Acoustic Enhancement systems are sound systems that utilize electro-acoustics (microphones, loudspeakers and amplifiers) to augment or generate reflected or reverberant energy.

These systems have been installed in Concert Halls, Opera Houses, Performing Arts Centers, and Multi-Purpose Venues



RUMC is a round, 12-sided space that wraps almost 180 degrees around the podium.

throughout the world. In addition, they have been installed in Houses of Worship to overcome a number of vexing problems that have compromised optimum acoustical delivery for many years.

Basic Acoustics

We should preface further discussion of electronic acoustical enhancement with a brief overview of natural acoustics. Direct sound arrives at the listener's ear without reflecting off of a surface. Early reflections are those sounds which bounce off of a surface and arrive at the listener's ear no later than 10 to 15 milliseconds later. Our neurology integrates reflections up to about 30 ms with the sound from the source - merging it with the direct sound. Later reflections are signals our neurology treats as being separate from the source, and can arrive from 30 ms to seconds later. The buildup of these combined early and late reflections is called reverberation. It is the sound that persists uniformly throughout the environment once the sound source is silenced. The measure of reverberation is RT-60 - the time it takes for sound to drop -60dB from its initial utterance.

In natural acoustics the reverberation time, and the level of reverberation, are determined by the cubic volume of a space, and the absorption characteristics of the surface treatments. Altering either the cubic volume or the composition of surface treatments will affect both reverb time and level.

Reverberation contributes to the perception and enjoyment of music, but can be disruptive to the understanding of speech. For speech, the sound designer wishes to minimize reflected energy that arrives 50 ms or more after the direct sound, and favor reflected energy generated from the direction of the sound source. However, if a venue is to be used for music it should have both longer reverb time as well as reflections and reverberation that envelop the listener.

Fighting Feedback

In any sound system reverberation contributes to acoustic feedback, a condition caused when sound from loudspeakers is picked up by the microphones. Feedback can be minimized by placing microphones closer to sound sources; keeping loudspeakers and microphones as far apart as possible; using highly directional loudspeakers to help focus sound to the listener; and by placing loudspeakers closer to listener and away from surfaces.

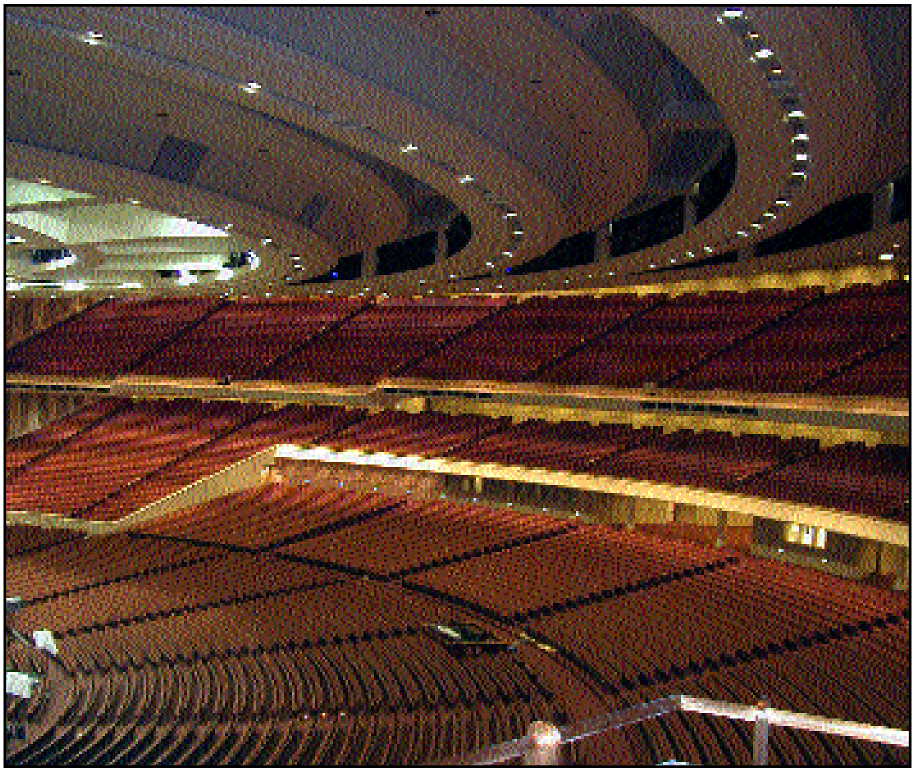
Conversely, generating an electronic sound field that sounds like natural acoustics requires ignoring all of these guidelines. As you might suspect, the success of early enhancement systems was quite marginal. This is because they could achieve necessary output level before going into feedback. But the research performed by David Griesinger at Lexicon and Steve Barbar at LARES Associates, together with advancements in digital signal processing, have produced the capability to significantly reduce the effects of acoustic feedback in such a system.

Called "multi-channel time-variant reverberation", the technology overcomes the feedback problem by generating a time-variant signal which de-correlates the path between the microphones and loudspeakers in real time. Put more simply, before a single frequency begins to feed back, the acoustic path is changed. This reduces the amplitude at that frequency, thereby reducing feedback.

Acoustic Enhancement

Utilizing multiple independent time variant signals fed to multiple loudspeakers, which are distributed throughout the venue, further increases gain before feedback. This technology has made it possible to design practical systems that produce a significant improvement in the perceived acoustics in a variety of spaces, hence the term acoustic enhancement. But there is much more to it than that.

"Reverberation is an important acoustic quantifier" says Steve Barbar, "However, it is but one of a number of important parameters that we use to describe our perceived lis-



The world's largest indoor conference facility seats 2100. House mix is 150 feet from the podium. The balcony extends another 100 feet. Enhancement consists of hundreds of concealed loudspeakers in the ceiling and underbalcony.

tening experience. Other critical measures include early decay time, clarity, envelopment, strength, and more. The acoustic quality for the two seconds of reverberation produced by shouting in a sewer pipe is not necessarily what we would desire in a good concert hall."

Likewise, the acoustical characteristics of a good venue might be equally out of place in a large church or cathedral - and there may be times when the acoustics of a cathedral are desired in a small church. The success of these systems depends, as always, on careful consideration of the real acoustic needs of the venue in question, and the resulting design and implementation of the enhancement system.

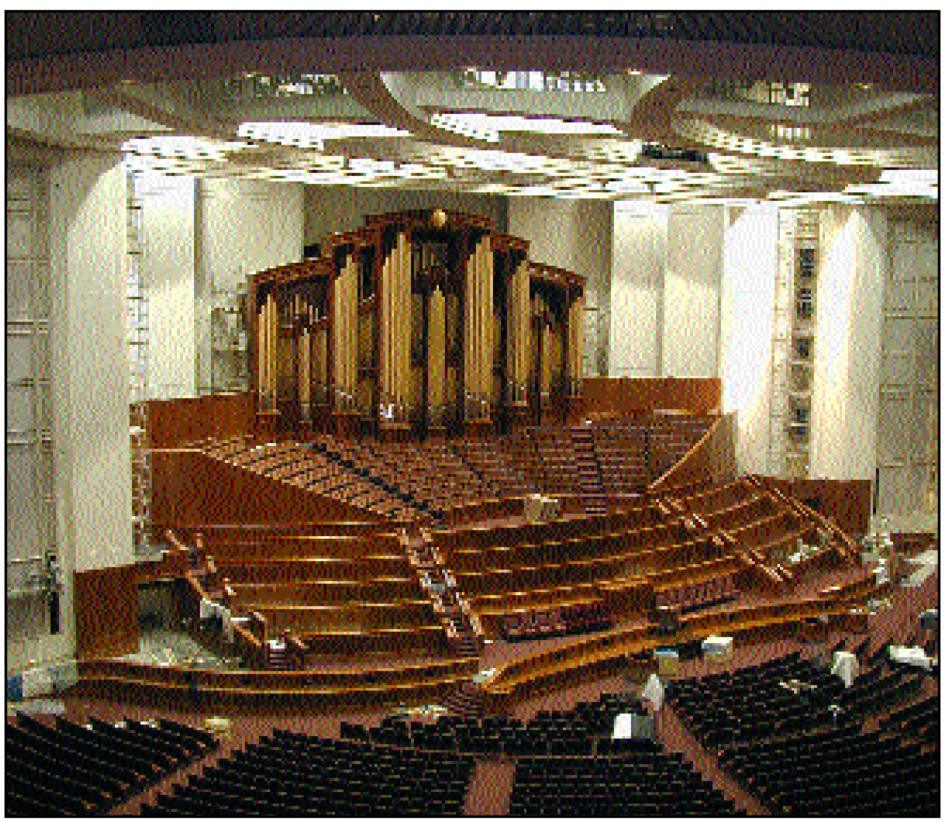
Many consultants and design/build contractors are discovering that with the use of this new tool, along with standard acoustical treatments and good sound design practices, they can deliver the acoustical conditions that the client desires, even when more than one condition is needed. From music requiring long reverberation times, to dramatic performances which require greater articulation and ambient warmth, a properly designed system can be altered to accommodate vastly different performance needs at the touch of a button.

Recently I traveled to three such installations and spoke with designers, consultants and contractors. These installations were selected because of the wide diversity in both the size of the venues and scope of their acoustical requirements.

Church of Jesus Christ of Latter Day Saints

One of the largest indoor spaces to use acoustic enhancement is the new Conference Center at the World Headquarters of the Church of Jesus Christ of Latter Day Saints in Salt Lake City. With more than 21,000 seats, it is the world's largest indoor conference facility. The complex, which takes up two city blocks in downtown Salt Lake City, also includes a 900 seat proscenium theatre, and is adjacent to the legendary Mormon Tabernacle, home of the Mormon Tabernacle Choir.

From day one, speech intelligibility was the most important consideration for the conference center. Although the space looks as though it should have at least three or more



The choir loft begins 50 feet behind the podium, and extends another 60 feet farther back to the organ façade. Choir enhancement is completely separate from house enhancement.

seconds reverberation time, when you clap from the middle of the seating area, you get the sense that very little comes back. Certainly you do not sense much if any reverberation. Even so, speech reinforcement is a challenge. The venue is host to the annual conference that features lectures and speeches from the church president as well as members of the General Assembly. Thus, it is imperative that the spoken word is communicated effectively throughout the venue.

The distances involved are daunting. The audio console is approximately 150 feet from the podium - and there is another 100 + feet from the console to the rear wall under the balcony. The choir loft begins fifty feet behind the podium, and extends another sixty feet farther back to the organ facade. Although the cubic volume is enormous, (it is larger than most sports arenas), the natural reverberation time falls below 1.4 seconds when unoccupied. This gives you some idea of the enormous amount of absorptive materials integrated in the building.

"The space was treated as if it were several decoupled venues that share the same sound source", says Steve Barbar of LARES Associates. "The acoustics in the choir loft have very little in common with conditions in the main seating area, which in turn, have little in common with the conditions experienced in the balconies."

It was very clear that the only way possible to meet the mandate for speech intelligibility, and simultaneously provide optimum acoustical conditions for the Tabernacle Choir and new pipe organ, was to incorporate electronic acoustic enhancement on a grand scale. If you were to superimpose the length of the tabernacle on top of the conference center, the tabernacle would end at the first rows of seats.

Deward Timothy of Poll Sound has been intimately involved with the installation of both the sound reinforcement system as well as the acoustic enhancement system. The primary sound system was designed by Jaffe Acoustics, and has been through various renovations in the past six years. The one constant in the venue has been the acoustic enhancement system. "The goal was to reproduce the Tabernacle sound in the new auditorium," said Timothy. "The Tabernacle Choir is used to singing in the tabernacle, which has a certain acoustical quality."

A canopy of loudspeakers overhead, supplemented by lateral arrays and fill speakers in the organ façade provide the acoustical energy in the choir loft. Four independent acoustics processors are used to optimize acoustic conditions for the choir. These both feed energy from one side of the loft to the other so that sections can hear each other, and provide the reverberation that the choir is accustomed to.

The enhancement system has two other equally important roles. First, the direct, reflected and reverberant energy is adjusted carefully throughout the venue to maintain impact, clarity, and envelopment. Additionally, microphones placed in front of the balconies pick up the sound of the congregation, and independent acoustics processors distribute this energy throughout the space. This creates a unified acoustic volume, enabling the congregation to participate in song with the choir.

Although a dead room with a low reverb time, there are many focused return echoes to the stage that are quite disruptive to a person who is on the stage. As a result, the enhancement system is also used as part of the general reinforcement system reducing the amount of energy necessary from the central cluster.

In total , the enhancement system consists of nine mainframes, eight zones, over three hundred speakers, and almost as many amplifier channels. The resulting effect is a space that can sound wet like the Tabernacle or dry like the natural conference hall.

This small hall has little reverberation, but has annoying reflections from any sounds that manage to escape the domed chancel area. Enhancement speakers are hidden on the front side of the beams.

Piedmont Community Church

Nestled in the hills of Piedmont, California, a small town next to Oakland, is a century- old community church that began as a loose collection of primarily Protestant worshipers. Today, the church is a solid community organization. The Music Minister, Steve Main, directs and performs choral and organ music from classical periods as far back as 800 A.D. Classical music is the focus in the church, as it has no contemporary bands and does not utilize praise songs in its services.

"Our acoustics are poor with lots of room returns coming back to you from the back," Main says, referring to the noticeable early reflections. The sanctuary is small, seating about 350, with dark redwood floors and pews, and an open-beam, pitched ceiling. The chancel area has a domed ceiling which has the effect of "capturing" the sound. As a result, both the organ and the choir have real difficulty reaching the audience with any envelopment. Sitting in the back the sound seems remote and decoupled instead of warm and intimate.

"This caused problems in picking repertoire", said Main. Main's music selections are admittedly a little eclectic. "I couldn't use things like 'plain chant' because it sounded dull and dead because of the acoustics." Gregorian Plain Chant, I learned, are simple vocal melodies that sound like singing a book out loud. "The same was true in playing the organ," he continued, "Every organist knows 'that sound' of the acoustics of the room sort of carrying the organ down the church and trailing off. We refer to it as a roll, and it just wasn't here in this church."

Main contacted an acoustician to explore whether changing the physical space might improve acoustics, which he quickly found to be impossible. The loud acoustical early returns might even be accentuated and made worse by trying to make the room more live. After visiting a church that had an electronic enhancement system, Main decided to pursue a similar solution for Piedmont and contacted LARES Associates. The system was designed by Steve Barbar consisting of a single mainframe, nine four-channel power amplifiers and 46 speakers. It was installed by BBI, a contracting firm based in San Francisco, and a full demonstration was staged by LARES prior to the church making a decision.

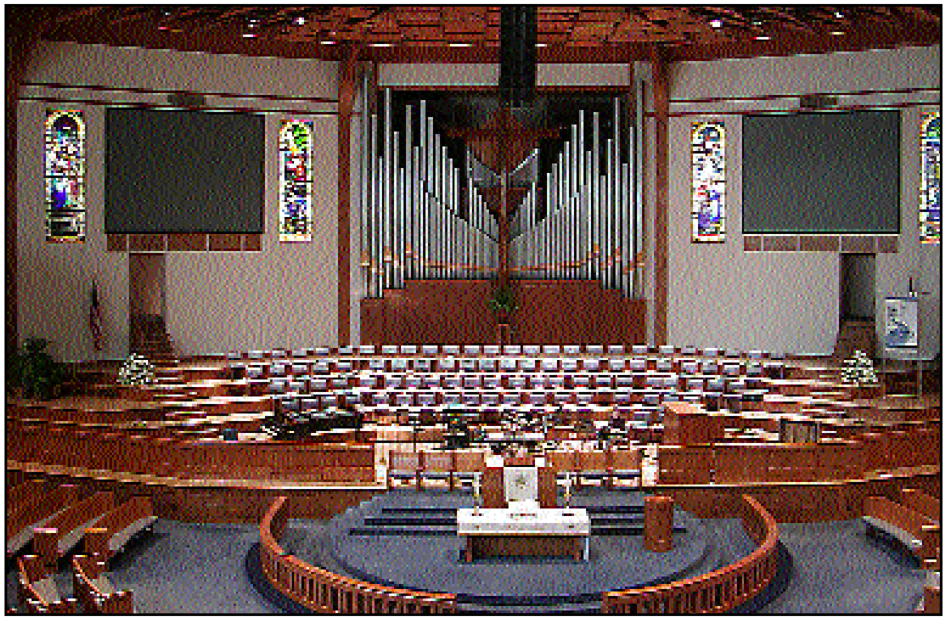
Because the loudspeakers were mounted to the beams in the church, the installation of the enhancement system brought with it a bonus of integrating sound reinforcement at negligible additional cost. Both the reinforcement system and the enhancement systems are under Crestron control. A touchscreen is located at the organ, and Steve Main has a hand-held wireless remote that enables him to recall system settings from anywhere in the church.

Steve Main describes the results in his own words. "The biggest change for us was not with loud music, but with soft. Before, it [the sound] would have fallen flat just past the performers, but now it floats in the sanctuary. To me, the drama in quiet music is in the acoustic behind it; that sort-of audible stillness in the reverberation trail. My professional alto soloist can now stand on the steps and sing a simple Shaker tune, unaccompanied, and it's just electrifying. We could never do that before. In performing I aim to the silence, meaning I let the energy fall off just enough before the next attack. With the enhancement system I can now direct and play to the new acoustics of the room."

Roswell United Methodist

Acoustic enhancement was recently incorporated into the upgrade of the sound system at this north suburban church just outside Atlanta, Georgia. The changes were part of a comprehensive effort to bring the worship space up to date with current worship technology including video display, theatrical lighting, and audio technology.

Jim Brawley of James S. Brawley and Associates designed the main sound reinforcement system and coordinated with Steve Barbar of LARES Associates on the design of the acoustic enhancement system for the choir. Stage Front Presentation systems in Savannah, GA installed both the sound and video systems in the church.



The choir loft canopy produces reflections that are almost at echo threshold. Enhancement created a "virtual canopy" for the choir.

Architecturally the church is a 12-sided round building with a large dome (Figure 1). The chancel, or stage, extends far enough out into the room that the pulpit microphone is almost directly under the center of the dome. Standing directly under the dome one can hear several distinct reflections of your own words, and thus it's difficult to keep speaking.

The biggest acoustical problem was the many echo returns from various sources. These echoes affected clarity for both speech and music. The church installed numerous absorbing and diffusing panels recommended by Jim Brawley. Doing this created a more neutral acoustical condition enabling the reinforcement system to function more effectively. The natural reverberation time in the church is approximately two seconds and with the added clarity provided by these improvements, the musical acoustics as perceived by the congregation are quite good.

In the choir loft, however, the acoustical conditions needed significant improvement. There are three choirs that perform at RUMC, the main 150-voice choir, a 14-voice ensemble, and the Michael O'Neal Singers, a professional group lead by the Director of Music, Michael O'Neal. "Our church had not been good for the performer," said O'Neal. "Since the room and the choir loft is so wide, they would sing but couldn't hear much of anything but themselves and the persons next to them. Altos couldn't hear the sopranos, and such, and that was detrimental to building any sense of ensemble. They were singing on Faith, if you will."

Brawley had experience with electronic acoustics and recommended installing a system in the choir loft. "There is a physical acoustical canopy above the choir," says Brawley, "but it's so high it's almost at an echo threshold. The thirty-two loudspeakers in the canopy speak instantaneously, shortening the distance by half and effectively making a 'virtual canopy' over the choir."

This virtual canopy is supported by 32 speakers under the floor to enhance the early floor reflections, and 4 speakers under each of the large projector screens for lateral energy. Brawley also had to design the right main system for the room which was a small format line array system with a gradient subwoofer design. "We were able to engineer it [the main system] to shoot under the balcony and over the communion rail and basically prevent any low frequency energy down to 50 Hz from hitting the wall behind the choir." This back radiation was crucial to control in order to have an effective

A central line array hangs close to the center of the dome to control sound to the main floor seating area.

enhancement system.

The perception of the congregation is that the performance of the choir has improved dramatically. Part of this is the sound system, but the acoustic enhancement system has enabled the choir to hear one another, improving ensemble performance. "The sound is so much better because of the simple fact that the performance level is so much improved," says O'Neal. "You can't build an ensemble if you can't hear...the system now allows a singer to hear other singers around him as well as other voices farther away...it helps him find his pitch, his timing, and of course the blending within sections, the balance between sections, even the detail of vowel formation. All because he can hear."

Applying Acoustic Enhancement

The application of enhancement systems has changed the way many churches approach their music ministry. The radical differences that can be heard with enhanced acoustics are proof enough for other churches to consider the technology. Each of the above cases has a different need for an enhancement system and each of them have upgraded their systems further since the original installation. For example, even with just a choir system, by adding additional system settings Roswell United Methodist has been able alter the reverberation to suit different music styles. There is now a warm resonance that accompanies organ solos and a cappella singing and they are doing more of it.

Careful consideration needs to be taken before recommending an acoustic enhancement system. One must first take measures to identify and solve blatant acoustical problems within the environment, as each of the above examples did. Noise intrusion from any source (street, HVAC, adjacent spaces, etc.), should be identified and eliminated. When using electro-acoustic enhancement there is a high likelihood that these noise problems, if not resolved, will be picked up by the microphones and amplified uniformly throughout the space.

Strong specular reflections should be treated with absorbing or diffusing materials, or by adjusting the main sound reinforcement system to at least minimize the reflection path. Electro-acoustic enhancement systems only add energy to a space. Corrective measures must be applied to the venue that produce natural acoustics with energy levels and time decays that are appropriate for those goals requiring the driest acoustical characteristics. This means that where utmost clarity is desired for the spoken word, much of the reverberant energy in the space must be absorbed. While such treatment is not usually associated with improving the natural acoustics for music, it is an important consideration for emulating the increased room volume in a larger space.

Finally, it is important to demonstrate the effect of an acoustic enhancement system. Each of the above venues were shown predicted results and heard a complete demonstration before making a purchase decision. The fact that you can prove your point demonstrates that there is science behind your art, and capability behind your technology.

References

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