

The Next Generation in Architectural Acoustics



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I would like to thank the NCAC for giving me this opportunity to reflect on the state of our industry. It is sometimes difficult to mark the transition from one paradigm or generation in a particular field to another. However, from my experience in the 20 years that I have been active in the field of architectural acoustics, I sense that we are entering a new generation, which we refer to as NexGen™ at RPG. I feel this is true for many reasons, some of which are elaborated on in this editorial. Briefly, we can witness that the average quality of acoustically designed spaces is steadily improving, with fewer really bad outliers; young firms are establishing reputations and several acoustical pioneers are handing over the reigns to a new crop of acousticians with equally pioneering spirits; proof of performance specifications of both absorptive and scattering surfaces are now standardized; acousticians are relying less on traditional pyramids, barrels and fabric wrapped panels and embracing more powerful modern surface treatments; computer modeling and auralization are becoming trusted design tools for acousticians; the quality of electro-acoustic systems has reached exceptional fidelity and today these systems provide not only enhancement, but true variable electro-acoustic architecture; and finally, computer measurement tools have evolved to the state where acousticians can easily evaluate architectural acoustic spaces and determine all of objective measures developed over the years.

The Next Generation of Acoustical Products and Proof of Performance Coefficients

It has been over a hundred years since Sabine established absorption as a quantifiable acoustical surface treatment and linked its relationship to reverberation time. Much has been accomplished with respect to standardization of the measurement of random incidence absorption coefficients in reverberation rooms and normal incidence absorption coefficients in impedance tube testing. Because of the need for absorption over different frequency ranges, especially mid and low frequencies, RPG has developed a complete range of low frequency shelving, low frequency band cut, mid band and high frequency shelving absorption products called Parametrix™. In our educational programs we strive to promote the use and understanding of the full absorption spectrum, rather than single number parameters like the NRC. The next generation of bass management plate systems providing absorption down to 50 Hz with a 4" depth are truly exciting. The many new demands for absorptive performance have given rise to a new generation of porous absorptive materials, including fiber-free polyester, melamine foam, cottons and sintered glass, transparent fiber free films and panels, absorptive plasters, absorptive woods and the new bass management plate absorbers.

It has now been 30 years, since Manfred Schroeder published his first paper on "Diffuse Sound Reflections from Maximum Length Sequences" JASA, Vol. 57, No. 1 (January 1975) and 20 years since RPG introduced the first commercial sound diffusor. We now know how to model, design, predict, measure, characterize, optimize and standardize sound diffusing surfaces. Much of this progress is a result of the development of Shape

Optimization, which combines boundary element and multi-dimensional optimization techniques to provide optimal surface shaping, and Aperiodic Modulation, using optimal binary sequences, to provide area coverage with minimal periodicity effects. These tools give us the power to optimize any scattering surface the architect envisions. I have attempted to provide a comprehensive treatment of all that is currently known about sound absorbers and diffusers in a reference text book entitled "**Acoustic Absorbers and Diffusers: Theory, Design and Application**" by Trevor J. Cox and Peter D'Antonio, Spon Press 2004. The palette of sound diffusing surfaces has grown from the simple number theory surfaces of the 1980s to the modulated and optimized diffusors (Moddiffusors™) of the 21st century. In addition to a large and continually growing palette of sound diffusors, we now have standardized measurement and characterization proof of performance procedures in place with the ISO 17497-1:2004 Acoustics -- Sound-scattering properties of surfaces -- Part 1: Measurement of the random-incidence scattering coefficient in a reverberation room and the AES-4id-2001 information document, which will be incorporated as Part II within the year. We can now fully document a scattering surface. In Figure 1, we show a complete specification for a sound diffusor. The amount of randomly incident sound is the familiar absorption coefficient, a (a in Fig. 1). The amount of randomly incident sound that is scattered away from the specular direction is the new coefficient s . Both a and s are the coefficients used in computer modeling programs. When evaluating the uniform scattering performance of a surface, however, one should not use s , because it says nothing about the uniformity or distribution of scattering. To evaluate a diffusor, one

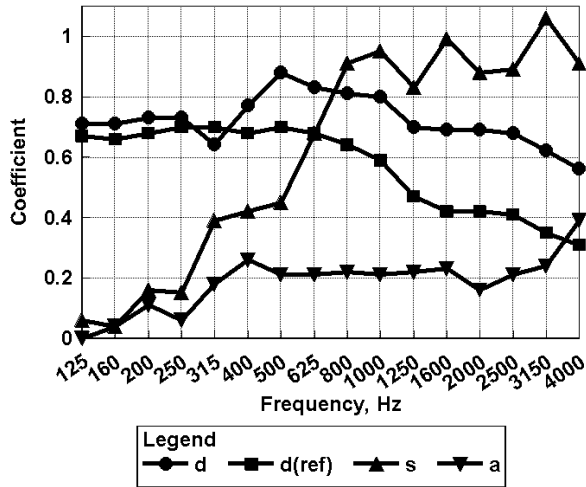
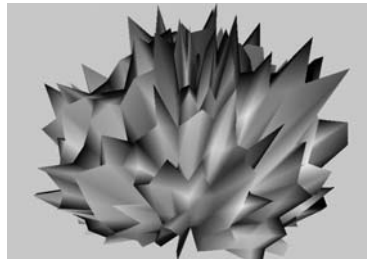


Figure 1. Complete specification for a scattering surface.

should refer to the diffusion coefficient, d , and the corresponding diffusion from a flat reflective panel of the same size, d_{ref} , for comparison. In addition, RPG has developed the capability to provide Virtual Reality Modeling Language (VRML) rotatable, color coded polar responses



VRML polar balloon (Grayscale) for a 2D optimized diffusor, illustrating the uniformity of scattering at 1000 Hz for normal incidence.

for scattering surfaces to provide a detailed view of how sound is actually scattered. All of the coefficients and VRML polar balloons are available online at www.rpginc.com. I would like to invite you all to attend a special session at the 150th Meeting, Minneapolis, Minnesota, October 17-21, 2005 to commemorate Professor Manfred Schroeder's incredible contributions to our field.

The Next Generation of Computer Modeling

Computer modeling has evolved from the early work using ray-tracing, to the image source model, to cone and pyramid tracing, to hybrid approaches using the image source model for low order reflections and randomized tail-corrected cone tracing for improved auralization. Most programs now include a scattering algorithm and acousticians can select from a number of powerful commercial programs. Today, computer modeling is part of most acousticians tool box and auralization has come into widespread use, now that scattering algorithms have been refined. One point we are constantly asked about is how to incorporate diffusion into the statistical models. It must be remembered that the statistical models already incorporate and assume complete diffusion. Therefore, the computer models are the best approach we have to model the actual effects of the placement and efficiency of both absorptive and scattering surfaces.

The Next Generation in Electroacoustic Architecture Systems

Electronic architecture systems have evolved from the first generation of analog recirculated tape delay sys-

tems, to the second generation of enhancement systems based on multi-channel assisted resonance systems. The third generation of enhancement systems included digital delays and processed reverberation on demand. An attempt was made to introduce wave field synthesis used in anechoic spaces into real architectural spaces. However, the required very large number of horizontally arrayed loudspeakers and their locations made this an impractical proposition for most halls. A significant step forward was achieved with the introduction of advanced reverberation processors using time variation in the feedback system to decorrelate the signal paths, providing stability and improved reverberation quality. We now know that natural reverberation contains no feedback. It is the result of high temporal-density omnidirectional incoherent reflections. Prior to the advent of digital signal processing, acoustic feedback provided a means of mimicking this natural process. Today, we have the power to more naturally simulate the natural reverberation and early reflection process more realistically through digital processing. Thus, there has been a paradigm shift. The goal today is to minimize, rather than embrace, the contribution of acoustic feedback and its artifacts to digitally simulate the most natural sounding reflection patterns. This is most effectively accomplished by generating the highest number of decorrelated reflection patterns to simulate the natural reflections from the room's boundaries. There has also been a second paradigm shift. Electronic architecture systems no longer are trying to superimpose the response of one room on another, *i.e.* the goal is not to make every room sound like Boston Symphony Hall. On the contrary, they are simply trying to make each room perform optimally, while respecting its unique acoustic character.

The next generation of electro-acoustic systems is now providing real variable electro-acoustic architecture and not just enhancement. Modern systems use the direct sound field to create early reflections, frequency dependent reverberation, area independent level control, using over a hundred decorrelated FIR signals, with no time variance or feedback. The same processor can provide one acoustic environment in a given space, multiple environments in a given space or multiple environments in different spaces, essentially an electro-acoustic server. In addition, these next generation enhancement systems may also be used in setting up complete acoustical immersion environments in which acousticians can auralize virtual environments with incredible realism.

In this brief editorial, I have tried to describe the path to the current state of our industry and how, in my view, we are turning the corner and entering an exciting new generation of architectural acoustics. On a personal note, it is very exciting that RPG is actively involved in advancing all of these leading edge technologies and products and we are staying true to our mission of continually expanding the acoustical palette through a dedication to fundamental acoustics research. My hope is that history looks on our achievements as favorably as we cherish those of the industry's founders.