

VARIABLE COUPLED CUBAGE FOR MUSIC PERFORMANCE

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This paper discusses the decay characteristics of concert halls incorporating partially coupled spaces, and the implications for the perception of acoustics quality. The paper also presents the design of a concert hall that includes both variable coupling and variability in design features, (both the width and height) of the hall and the strength of the early reflections. This hall can optimize almost instantly the acoustics environment to suit individual musical works. Some of the halls designed and built in the early years of the twenty-first century will surpass the acoustics quality of the Meyerson-McDermott Concert Hall in Dallas, Texas.

In the literature published orally and in journals prior to the 1970's a double-slope reverberation trace was branded as anathema--the mark of acoustics failure. Concert hall designers all over the world agonized over the core question: how to achieve adequate clarity and still provide the reverberation that symphony conductors requested. Concert hall designers in the 1950's and 1960's debated how much could the reverberation time goal be compromised (reduced) in order to insure that a new hall would not be criticized for lacking clarity. In the literature of that period there are frequent references to 'compromise reverberation time.' The hall designers acknowledged that music directors wanted 2.1 seconds of reverberation at 1000 Hz, but to achieve satisfactory clarity they usually set themselves a shorter mid-frequency reverberation time goal, in the region of 1.65 to 1.75 seconds. In some cases 1.65 seconds to 1.75 seconds became the mid-frequency reverberation time goal in order to keep the building costs within funding limitations established by the building owner. In still other instances a compromise reverberation goal was selected in order to benefit the acoustics for events other than symphony concerts.

A concert hall design which incorporates a large, hard secondary chamber abolishes the need to sacrifice reverberance for the sake of clarity, or to give up clarity in order to satisfy musicians demands for lengthy reverberation. The experienced listener can come out of a concert in a hall with properly designed partially-coupled chambers and think: "The sound of this room provides excellent reverberation yet the sound simultaneously has an unusual degree of clarity."

There are a growing number of halls with a secondary chamber partially coupled to the primary chamber. Many Artec-designed rooms have reverberance chambers. We list a few examples: Festival Hall in Tampa, Florida; the Meyerson-McDermott Concert Hall in Dallas; the Centre in the Square in Kitchener, Ontario; the Great Hall at Hamilton Place, Hamilton, Ontario; the Wascana Centre in Regina, Saskatchewan; Crouse Hinds Concert Theatre in Syracuse, NY. In some of these built Artec designs the secondary chamber is just behind the

musicians, in some it is above the audience, in some it is at the sides of the audience chamber.

When one asks *musicians* to describe the attributes of sound they find most supportive or most inspiring in spaces for music performance, most frequently they list warmth, fullness, definition, reverberance, and singing tone. Musicians also employ hundreds of other words or phrases to communicate to concert hall designers their "wish list" for acoustics attributes of new halls. A sampling might include: good loudness balance; warm; mellow; natural; resonant; floating; transparent; no distortion; not glassy; not cold; not harsh; not muddy; brilliant (but not too brilliant). The descriptions are almost without end.

One of the basic questions in concert room acoustics is: how many independent aspects are there in the perception of room acoustics quality? Many acousticians have tried to answer this question---and have come up with many different responses. Recently one of the authors, [Kah95], put forward some tentative explanations on why the answers come out so differently. The reasons lie both in the psycho-experimental methodology employed and in the details of the sound fields selected for the studies.

In his "Reverberation" paper [Sab00] and [Sab22]), W.C. Sabine claims that there are three and only three independent aspects in the perception of room acoustics quality: loudness, balance and reverberation. Sabine was thinking of the decay as being exponential right from the very beginning of the response of the room and throughout the entire decay. We now know about the importance of early reflections and that no "real" decay will ever be perfectly exponential from the beginning (though many are very close to exponential after approximately 200 msec).

Let us go back to the "Sabine" decay, neglecting all spectral and spatial aspects. For a constant sound power level (Sabine's first aspect), there is only one more independent parameter-----which we can call reverberation time, or anything else we like. A whole set of objective criteria linked to the perception of reverberance and clarity are completely correlated to this one independent parameter: reverberation time. Therefore, for a Sabine decay there is no need to define criteria such as the early decay time EDT (Atal, Schroeder and Sessler, [Ata65]; Jordan, [Jor70]), the clarity index C80 (Abdel Alim, [Ali73], Reichardt, [Rei75]), the Deutlichkeitsgrad (D, [Thi53]), the central time (Schwerpunktszeit, [Kür72]), etc.

In real halls however the decay is never perfectly exponential, and therefore there *IS* a need to define the different objective criteria. What happens in partially coupled volumes is that the deviation of the decay from exponential is increased. A varying slope occurs and the late decay is longer than the early decay. Adding variable coupling allows one to shift the transition in the decay slope backwards or forwards in time.

From a perceptual point of view [Kah95] we can differentiate the following aspects of room acoustics quality: (the list is fairly detailed in respect to the aspects governed by the decay characteristics of the room, but no spatial nor spectral aspects are included) :

OVERALL LOUDNESS: it can be shown that the perception of overall loudness is the sum of the perceived energy of the early part of the room impulse (perception of the loudness of the sound source) and the perceived energy of the late part of the room impulse (perception of the room effect; including masking effects of the early energy on the reverberant energy);

REVERBERANCE: can be subdivided into two slightly different aspects. RUNNING REVERBERANCE is the reverberance that is perceived while music is played continuously. The perception of running reverberance is governed by the early decay time (either calculated over the first 15 dB of the decay or over the first 380 ms of the decay [Gri95a]). STOPPED REVERBERANCE is the effect that is heard at the termination of the sound and is the "classical" reverberation time;

DEFINITION OF THE ATTACK: the definition of the attack is influenced in a complicated way by several objective criteria. First of all, overall loudness enhances the perception of the definition of the attack. Secondly, it is linked to the question whether any one part of the early response of the room (direct sound, first reflections and secondary reflections) is predominant in the early response of the room. Thirdly, the early response of the room is evaluated against the continuous "background" of the reverberant tail of the room response.

If we want to simultaneously optimize these different perceptual aspects, we HAVE to achieve a room decay which is not exponential. But there is one more question: having seen that, within certain limits, the individual aspects in the perception of room acoustics quality can be optimized individually, should we not optimize them *differently* for individual musical works? Each musical work has specific demands on the acoustics environment of the room-----and, therefore, for each musical work there is a different set of "optimal" values of the objective criteria determining the perceptual aspects of the acoustics environment of the room. The concert hall designer can not aim for "optimum acoustics for symphony music." No such animal exists. What can exist is an acoustics environment which is well-adapted (or even perfectly adapted) to a particular musical work being performed. This is why variability of a wide scope will dramatically enhance the acoustics quality of a concert room.

Consider the acoustic difference if we compare a hall with the side walls positioned about four feet from the edge of the main floor seating with a hall with the side walls about twenty feet out to the side. The size of the audience area stays stable, and the position of the audience area does not shift.

Similarly, consider the acoustic difference if we compare a hall which has a complete horizontal ceiling about 35 feet above the concert platform with another hall with a horizontal ceiling eighty feet high. The audience seat count, and positioning of the seating areas remains fixed.

We propose a concert hall that incorporates all four of these hall designs into one room, and for discussion purposes we are calling it the Hall for the Century XXI.

We show on pages 5 and 7 an Artec concert hall design which is the logical next step after the Artec designs for the Philadelphia Orchestra, Luzern, Singapore, Dallas, Birmingham, Miami. This design for a very variable hall----a hall with both variable width and variable height----is derived from design studies we did in the late 1960's and early 1970's----the designs did not pass muster at that time with owners or architects.

In the Meyerson hall in Dallas (designed in 1983) the reverberation chamber is above the highest seating areas. In Artec's concert rooms for Miami, Singapore and Luzern the floor of the reverberance chambers is positioned about seven meters lower than is the case in Dallas and Birmingham. In the "Hall for Century XXI." the lowest portions of the reverberance chambers are at the level of the main floor seating area. This evolutionary design has some intriguing aspects, incorporating fundamental improvements in the nature of the music/acoustic experience for symphony music.

Consider, in the XXI design, that the bulk of the reverberation chamber is at such a low elevation that the concert-goer will be really embraced by the resulting acoustic environment (quite a difference from the Meyerson-type room where some listeners identify the source of the reverberance as being from overhead).

But there is still another acoustics benefit inherent in this XXI concert hall design---the fact that the arrays of hinged doors at ALL levels of the side tiers give the music director much more control of definition than is the case at the Meyerson. In the XXI hall, with all of the side wall doors closed, the combined reflection action of the shut doors and the side tier soffits manufactures powerful sound reflections arriving from the sides of the listeners. By opening some or all of the side tier doors, the reflections from the sides of the room are almost completely removed. The music director, by adjusting the canopy heights and by determining which side tier doors are opened, is given an important new tool for achieving in one concert room a variety of optimum music/acoustic environments---enough variability to tailor the acoustics conditions to suit most of the music literature being performed today and hopefully, most of the music compositions that will be created in the 21st century. Today's repertoire in itself is already encyclopedic----Haydn, Torke, Shostakovich, Wagner, Orff, Purcell, Corigliano, Puccini, Boulez, Bruckner, Barber, Janacek, Ives, Verdi, Honegger, Vivaldi, Poulenc, Stockhausen, Scriabin, Mahler, Berlioz----but this broad spectrum of music sound will be stretched even wider during the next hundred years.

A key feature of the XXI design is the "full-ceiling" vertically moving canopies which Johnson has used previously in small halls at Furman University and Macalester College. Total seat count of Hall XXI is about 1950.

Figure 1 provides sketches of some of the architectural variability provided by the manually-operated side tier doors. Setting A provides a narrow room with a rather low ceiling, but with all 3rd the seats available for sale. This setting would be well-matched to the acoustics needs of recitals, conference meetings, and chamber orchestra repertory.

Setting B provides, with the doors open, a rather wide room (35 meters), and a halfway setting of the largest

canopy segment. This setting, or modest adjustments to it, will be appropriate for the heart of today's repertory, early Beethoven, Brahms, etc.

Setting C provides a room as high as a large church or a small cathedral, and 35 meters wide. This setting or modest variations of it will be used by the music administration for organ recitals, large scale choral/orchestral works such as Janacek's Glagolitic Mass, Shostakovich Eighth Symphony, Walton's Belshazzar's Feast, the Verdi Requiem. The strings/woodwinds canopy segment is illustrated at one of its average working heights, and the other two canopies are shown at their highest elevations.

Figure 4 (main level) shows the basic layout. There are reverberation chambers in the corners immediately behind the chorus/audience seating. Along the sides of the audience chamber there are audience foyers which double as reverberance chambers. Not shown is the storage garage (underneath the chorus seating and the organ chamber) for the wheeled platform with castered musician's risers when it is pushed back into the garage in order to provide a flat stage platform.

Figure 3 shows the reverberance chamber above the audience area. The dashed lines close to the ceiling show the highest elevations of the three vertically-moving canopies or ceilings. Figure 2 shows the largest ceiling section positioned at one of its settings, and it is also indicated with dashed lines at three higher elevations. This large canopy can also be lowered down to the level of the tier 2 spandrel, thus eliminating tier 2 as a functioning seating level. This would promote an appropriate acoustics environment for events that can sell only a small percentage of the full seat count. (Tier number 2 [top tier] has about 370 seats). Figure 2 also shows how the side lobby/reverberance chamber extends up from the main floor level through the levels of tier one and tier two.

Figure 5 is a transverse section taken through the concert platform area. The vertically-moving canopy shown here is the segment directly above the percussion and brass sections. This "brass" canopy is shown at one of its elevations, and near the top of this transverse section two of the many possible settings of this canopy are indicated by dash lines.

Figure 6 shows the reverberance chamber behind the chorus/audience seating. The three gray tone areas indicate the three canopy segments---the "strings/woodwinds" canopy (the circle), the "brass" canopy, and the large canopy above the audience area.

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