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Electroacoustic Architecture: Is it Green?

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Electroacoustic Architecture systems offer a means of changing the acoustic properties of a room electronically. They are an alternative to physically variable acoustics, where acoustic properties are changed by retractable curtains and doors opening to reverberant chambers, etc. This paper will address the question of whether Electro Acoustic systems are a Green alternative to Physically Variable acoustics. In order to have a reverberation time appropriate for Symphonic music, a room must have a large cubic volume, and hard heavy surfaces. In contrast, in a room with an Electro-Acoustic system, the physical reverberation time is desired to be low even at low frequencies. Therefore the cubic volume can be low and surfaces can be made of a lightweight material over an airspace. This affects the amount of energy needed to deliver materials, construct of the building, and operation of HVAC and lighting systems. A lower volume building means less pollution and waste during construction, and allows for more open space around the building, and/or higher development density. Electroacoustic systems can easily be designed as a renovation, thus recycling existing buildings. Case studies will be reviewed demonstrating these issues.

1 INTRODUCTION

Two approaches exist for constructing a venue whose acoustics can be changed.

One method is to physically alter the room for each type of performance. Curtains or rotating panels can be employed to add or remove absorption. Moving ceilings or doors to coupled chambers can be used to control the cubic volume. This method will be referred to as "passive" because it is the amount of sound that is removed from the space that is being controlled.

Another method is to use microphones, signal processing, and speakers to add reverberation and early reflections to the room[1,2,3]. Gain between the microphones and speakers can be used to

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reduce the effective absorption in the room. Reverberation processing between the microphones and speakers increases the effective cubic volume of the room. This method will be referred to as “active” because it is the amount of sound that is added back to the room that is being controlled.

2 DIFFERENCES IN CONSTRUCTION

2.1 Cubic Volume

The recommended reverberation time for Symphony performances is so long that essentially all of the acoustic absorption must be removed from the room and only the audience absorption and the cubic volume control the reverberation time. Beranek[4], for instance, writes, “all carpets, draperies, and sound-absorbing materials must be eliminated from the hall, and the audience must be seated in as small an area as possible”. Therefore, keeping the number of seats constant, the cubic volume of a space with Passive Acoustics is determined by the type of performance which needs the longest reverberation time. Beranek[4] calculates the average symphony hall is 8.9 m^3/seat. Egan[5] recommends 8.5 to 12.7 m^3/seat. Makrinenko[6] recommends 8-10 m^3/seat for symphony and 10-12 m^3/seat for organ. Passive Acoustic venues in Dallas, Birmingham[4], and Luzern[7] all exceed 11 m^3/seat.

Current Active Acoustic systems can only increase the reverberation time of a room. Therefore, the cubic volume and amount of absorption in such a room is determined by the type of performance which needs the shortest reverberation time. Egan[5] recommends 5.6 to 6.7 m^3/seat for “multi-purpose” rooms. Gade[8] recommends 5 m^3/seat for “drama”. Knudsen and Harris[9] recommend less than 5 m^3/seat for “theater”. Makrinenko[6] recommends 4 to 5 m^3/seat for “speech”.

A venue designed with Active Acoustics that accommodates performances ranging from cinema/speech to symphony/choral/organ, will require less than half the cubic volume as a venue using Passive Acoustics.

2.2 Surface Density

Many authors[4,6,9,10,11] recommend a longer reverberation time at low frequencies than mid and high frequencies for music performances. To accomplish this, a venue with Passive Acoustics must have hard heavy surfaces. In *Concert and Opera Halls*, Beranek[4] writes, “In general, all surfaces, except the stage floor, should be of heavy, dense material. This theme will be repeated many times in this book". Egan[5] writes, “avoid thin, lightweight materials".

Many of the same authors[9,11,12] recommend the reverberation time at low frequencies be the same as the reverberation time at mid and high frequencies for speech. Therefore, venues with Active Acoustics benefit from lightweight materials over an airspace which absorb low frequencies.

2.3 Under-Balcony Design

Halls with Passive Acoustics are limited in the height and depth of under-balcony areas. Beranek[4] and Gade[8] recommend the depth of an under-balcony area should not exceed twice the height. Egan[5] and Makrinenko[6] recommend the depth should be less than 150% of the height. By placing speaker and microphones in under-balcony areas, venues with Active Acoustics may have deeper under-balcony areas with lower ceilings.

2.4 Acoustical Materials

With a Passive System, a reverberation change of 0.2 seconds to 0.6 seconds is feasible by introducing large amounts of material such as the draperies, banners, or pull out absorptive panels. The amount of material, space to "hide" the material when not in use, and control system including motors and pulleys to operate the more robust systems is extensive and costly for larger amounts of variability. Jackson Hall in the Robert and Margrit Mondavi Center for the Performing Arts is an extreme case. The venue has approximately 20,000 square feet of drapery that can be exposed to the audience chamber to provide a 1 second change in the reverberation time. The addition of auxiliary reverberation chambers (Section 2.1 above) is the typical design approach when large amount of variability is desired in a "passive" system.

With an Active System however, the design of the space will require fixed absorptive elements to provide a flat, "dry" reverberation time across all frequencies, and to address unwanted acoustical issues, such as echoes. The quantity of material would be typically less than the material used in the "passive" example due to the decreased volume of the audience chamber. The active acoustic system then extends the reverberation time to the desired upper end and can be easily modified in the future to provide more flexibility.

3 LEED POINTS: FULFILLING THE REQUIREMENTS

3.1 Reuse

Because Active Acoustic systems do not require modifying the cubic volume of a building, they make it possible to reuse buildings that would not be reused, or would be more extensively renovated otherwise. This facilitates the fulfillment of Materials & Resources Credit 1.1 "Building Reuse – maintain Existing Walls, Floors, and Roof" and Credit 1.2 "Building Reuse – Maintain Interior Nonstructural Elements". When the existing building is in a sufficiently dense community, Sustainable Site Credit 2 "Development Density and Community Connectivity" can be fulfilled because it is a "previously developed site". Zellerbach Hall, on the campus of UC Berkeley, was renovated with an Active Acoustic system with 100% reuse of existing walls, floors, roof, and nonstructural elements.

3.2 Efficiency

Knudsen and Harris[9] write, "There are many advantages in keeping the volume per seat at a low value. […] Maintenance costs for lighting, cleaning, redecorating, air conditioning, etc. are correspondingly lowered". Venues with Active Acoustics require less than half the cubic volume of their Passive Acoustic counterparts. This facilitates fulfillment of Energy & Atmosphere Prerequisite 2: "Minimum Energy Performance", and Credit 1 "Optimize Energy Performance". Nokia Concert Hall in Tallinn, Estonia was designed with an Active Acoustic system and has only 6 m^3/seat. Figure 1 shows that the Active Acoustic system at Nokia Concert

Hall can achieve short reverberation times appropriate for Speech and Theater, up to the long reverberation times appropriate for Symphony, Organ, or Choral Music.

3.2 Density and Footprint

Because venues with Active Acoustics require less than half the volume, and can have deeper under-balconies, they can have a smaller footprint. A smaller footprint can contribute to yielding a higher community density, or more open space. This could contribute to fulfilling Sustainable Sites Credit 2 "Development Density and Community Connectivity" or Sustainable Sites Credit 5.1 "Site Development – Protect or Restore Habitat", and Sustainable Sites Credit 5.2 "Site Development – Maximize Open Space". Nokia Concert Hall, mentioned earlier, also has under-balcony areas that are deeper than would be recommended for a hall with only Passive Acoustic treatment. Figures 2 and 3 show plan and section views of Nokia Concert Hall.

4 LEED POINTS: FULFILLING THE INTENT

Active Acoustic systems also help fulfill the intent of certain LEED credits, even though they do not fulfill their requirements as currently stated. These efficiencies may lead to an Innovation in Design credit.

Materials and Resources Credit 2 – "Construction Waste Management" states that its intent is to "divert construction and demolition debris from disposal". When used in a renovation project an Active Acoustic system is likely to result in less demolition than a Passive Acoustic solution. By requiring less than half the cubic volume, a new project using Active Acoustics needs less construction overall and therefore it is reasonable to state there will be less construction debris.

Materials and Resources Credit 3 – "Materials Reuse" states its intent is to "reduce demand for virgin materials and reduce waste". Again, by requiring less than half the cubic volume, and a lower surface density, a new venue using an Active Acoustics demands less virgin materials and produces less waste. Northland Church in Longwood, FL was designed with Active Acoustics and has a web-truss supported ceiling and walls made of gypsum board over an airspace.

Materials and Resources 5 – "Regional Materials" states its intent as "reducing environmental impacts from transportation". Even though an Active Acoustic system does not effect the region materials come from, requiring less cubic volume, and lower surface density means leads to less transportation of materials.

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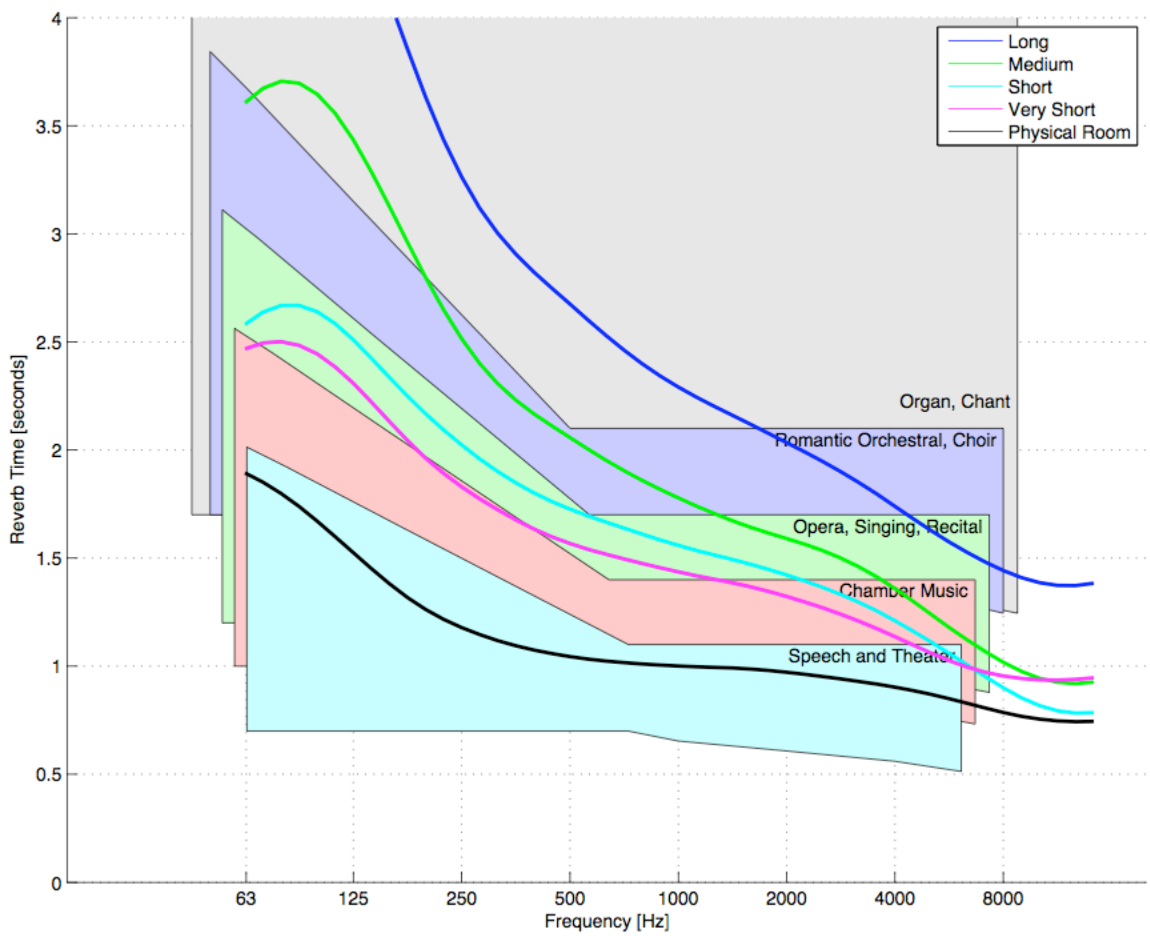

Fig. 1 - Reverberation Times at Nokia Concert Hall, Tallinn, Estonia

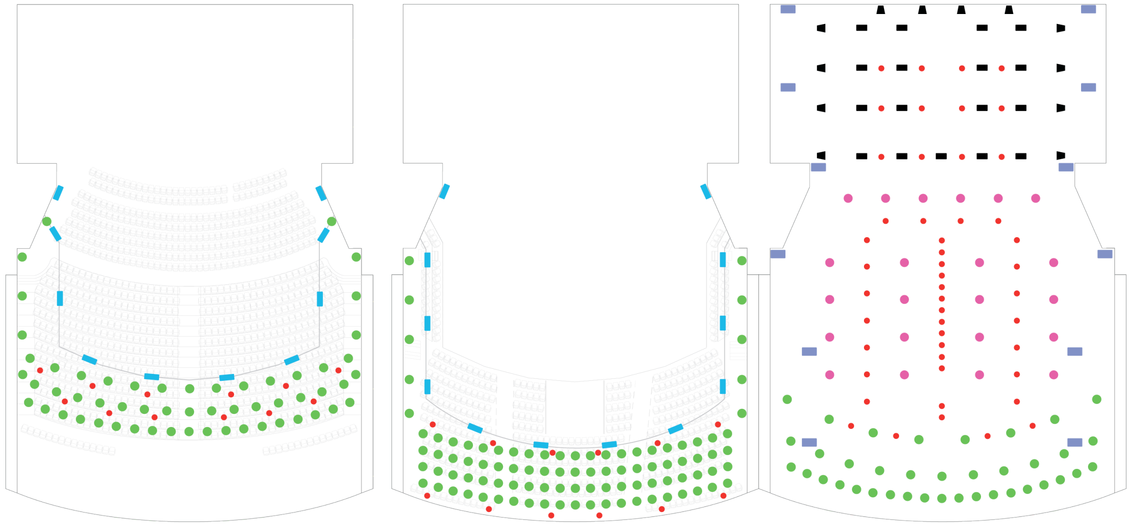

Fig. 2 - *Plan Drawings of Nokia Concert Hall, (from left to right) under-balcony 1, under-balcony 2, ceiling.*

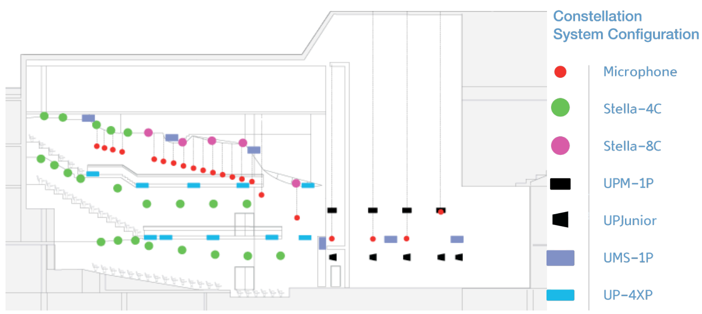

Fig. 3 - Section Drawing of Nokia Concert Hall, Tallinn, Estonia