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Electronic Shell—Improvement of Room Acoustics without Orchestra Shell Utilizing Active Field Control

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ABSTRACT
This paper introduces an example of the Electronic Shell acoustic enhancement system that was installed in a multi-purpose hall without an orchestra shell. The system is based on the concept of Active Field Control using electro-acoustic means. The three objectives of this system were 1) the enhancement of early reflection for performers, 2) the increase of the reverberation time and the total sound energy on stage, and 3) the enhancement of early reflection in the audience area. The application of this system showed an improvement of about 1 to 2 dB in ST_{early} and more than 2 dB in G in the audience area, which is equivalent or better performance than a simple mobile type orchestra shell.

1. INTRODUCTION

Multi-purpose halls are used for a variety of purposes, such as lectures, light music, drama, and acoustical concerts, whose optimum acoustical conditions are different. Typically, lectures, light music, drama, and the like, which require clarity, are performed with stage curtains, while acoustical performances use orchestra shells to support performers and efficiently transmit reflections to the audience area.

When musical applications are added to a facility whose prior usage is not for musical performances, such as a lecture hall, installation of an orchestra shell may be considered in order to meet appropriate acoustic conditions, but sufficient storage space is often not available. Moreover, campus festivals and events often consist of numerous programs that have different ideal acoustic conditions, which makes it extremely difficult to move and install an orchestra shell in the limited available time frame.

This report introduces examples of multi-purpose operations using an acoustic enhancement system that was configured by installing microphones and loudspeakers on the stage and near the proscenium instead of using a simple mobile type orchestra shell. These operations are held in small to medium-size multi-purpose halls, school lecture halls, and the like.

2. ACOUSTICAL CHARACTERISTICS OF ORCHESTRA SHELL

Acoustic problems that arise when acoustic instruments are played on the stage in a multi-purpose hall without orchestra shell are (1) a lack of effective reflections on the stage, which makes playing difficult because the performers cannot hear the sound produced by themselves or other performers, and (2) insufficient effective reflections in the audience area [1]. Typically, various forms of orchestra shells are installed to solve these problems. Reports show that large orchestra shells on the sides and ceiling surrounding the stage area achieve about 5 dB enhancement of ST_{early} on the stage and about 1.5 to 2 dB enhancement of *Strength G* in the audience area, while the change in reverberation time (*RT*) is slightly above 0.1 seconds [2]. On the other hand, when a simple mobile type orchestra shell without ceiling reflector is used, our on-site measurement results showed 1.6 dB enhancement of ST_{early}, 2 dB enhancement of *G* in the audience area, while the change in the *RT* is less than 0.1 seconds. These results could be a guideline of objective parameters to evaluate if alternative methods are effective for the improvement of acoustical conditions on the stage.

3. ACTIVE FIELD CONTROL

The Active Field Control (AFC) system is an acoustic enhancement system that was developed to improve the acoustic conditions of a space so as to match the acoustic conditions required for a variety of different types of performance programs. This system is unique in that it uses FIR filtering to ensure freedom of control and the concept of spatial averaging to achieve stability with a lower number of channels than comparative systems [3][4].

Fig. 1 shows an overview of the system. Sound picked up by microphones is amplified and digitized by an HA and AD unit and then processed by a signal processing unit. The resulting signals are assigned to multiple output channels through the use of a level matrix. The signals are then amplified by amp units and reproduced through multiple speakers. Because the sounds reproduced by the speakers vary with the conditions under which the speakers are installed, compensations must be made for these variations in each individual speaker during the tuning period. Also, to adjust the spatial impression of the reproduced sound field, it is necessary to specify different delay and gain values for each speaker. That is why each speaker is normally driven by an independent amp channel.

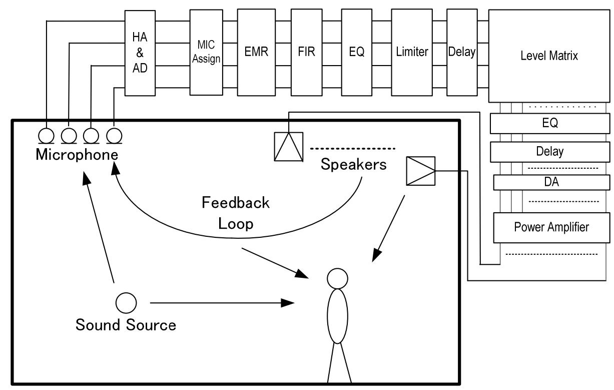

Fig. 1 Overview of the AFC system.

Because the microphones and speakers are set up within the same space, the sound that is reproduced by the speakers is picked up again by the microphones and then reproduced again by the speakers. This creates a feedback loop between the microphones and speakers. When the gain between the microphones and speakers exceeds a given amount, this feedback loop results in self-exciting oscillation, which can cause feedback noise. The difference between the system operating state and the gain value that leads to feedback is called the feedback margin. When the overall gain of a system is constant, the feedback margin between a specific microphone and speaker increases as the number of independent channels increases. Conversely, when the feedback margin for each channel is constant, as the number of independent channels increases, a larger overall system gain can be achieved, and acoustic conditions can be changed with greater freedom. That is why it is common to create a system that comprises at least four independent channels by setting up at least four microphones in a venue and sending the signal picked up by each microphone to a speaker without mixing the signals. In AFC, an EMR (electronic microphone rotator) is used to switch combinations of microphones and speakers over time. This results in the spatial averaging of loop gain and the flattening of the loop frequency characteristics for the overall system. This in turn makes it possible to achieve stable control with a smaller number of microphones.

Because the adjustable range for each channel is determined by the combination of the electrical transfer characteristics from the head amp to the speaker and the physical transfer characteristics from the speaker to the microphone, increasing the size of FIR filters in the signal processing unit increases the controllability of the system and makes it possible to implement a variety of different changes. Normally, when the size of FIR filters ranges from tens to hundreds, the modifications made by these FIR filters are used to flatten the frequency characteristics of the loop gain, which is a transfer characteristic of each channel. When thousands of FIR filters or more can be used, they can be used to adjust acoustic conditions, including time axis variation characteristics.

Based on this concept, we configured the following “Electronic Shell” system to improve the sound field of multi-purpose halls without orchestra shells.

4. CONFIGURATION OF ELECTRONIC SHELL

The three objectives of Electronic Shell were 1) the enhancement of early reflection for performers, 2) the increase of the reverberation time and the total sound energy on stage, and 3) the enhancement of early reflection in the audience area. The goal was to achieve acoustic characteristics that are at least equivalent to those obtained by simple mobile type orchestra shells.

The Electronic Shell system implementation examples described here are of two types, corresponding to two different patterns: System A, which considers the front of the stage according to the assumed sound source area, and System B, which considers the entire stage area. System A used four directional microphones to cover the assumed sound source area whereas System B used two rows of four microphones to cover the entire stage area. System A used three rows of four loudspeakers (12 total) while System B used four rows of four loudspeakers (16 total). Table 1 shows the detail of the auditoriums where the systems are installed. Fig. 2 and 4 show the respective system configurations of the auditorium. Fig. 3 and 5 show the respective block diagrams of the systems. The concept of spatial averaging including EMR was not applied to the systems because the systems are designed mainly to handle the early reflection domain.

All microphones and loudspeakers were installed on batons on the stage. Further, four dedicated loudspeakers were installed in the proscenium to ensure effective reflections in the audience area. In System B, the combinations of microphone and speakers were crossed in the depth direction of the stage in consideration to the uniformity of the effect of the system distributed to the performers in the entire stage area.

Auditorium	Number of Seats	RT (sec) System Off	RT (sec) System On
Fairport HS (System A)	981	1.6	1.8
Phelps HS (System B)	991	1.4	1.4

Table 1 Specifications of the auditoriums.

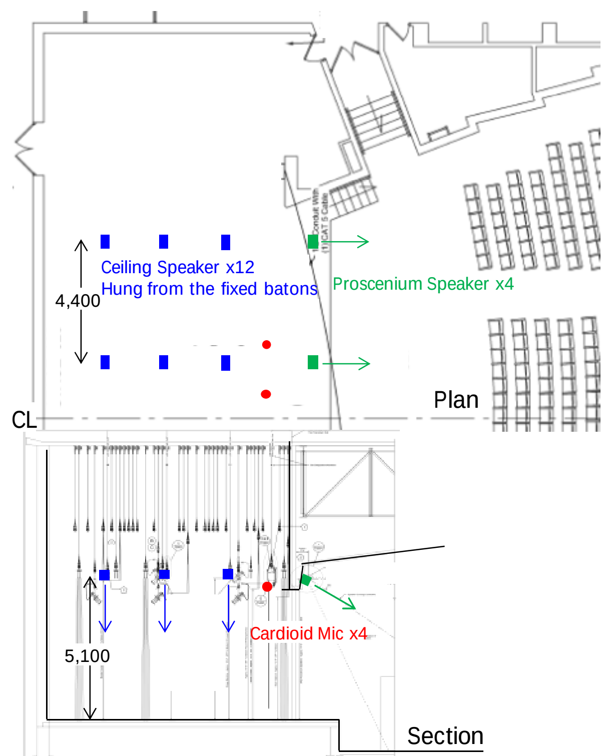

Fig. 2 Configuration of the auditorium (System A).

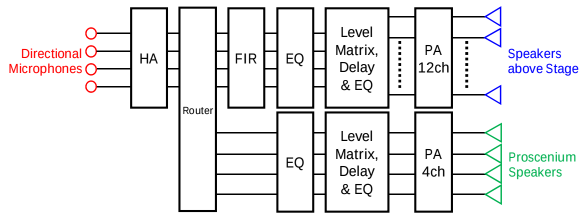

Fig. 3 Block diagram of System A.

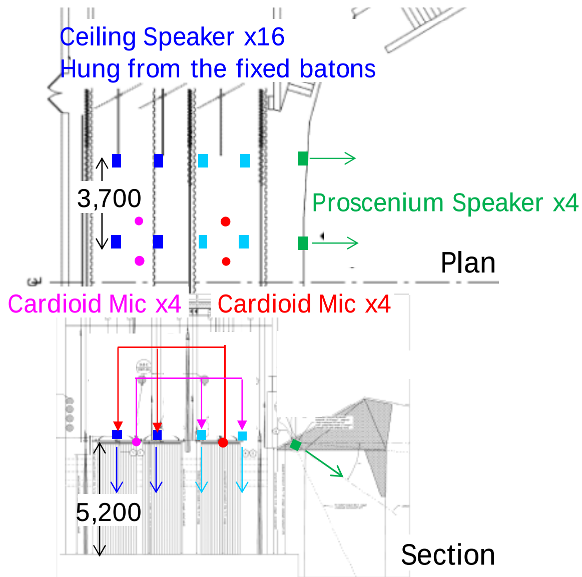

Fig. 4 Configuration of the auditorium (System B).

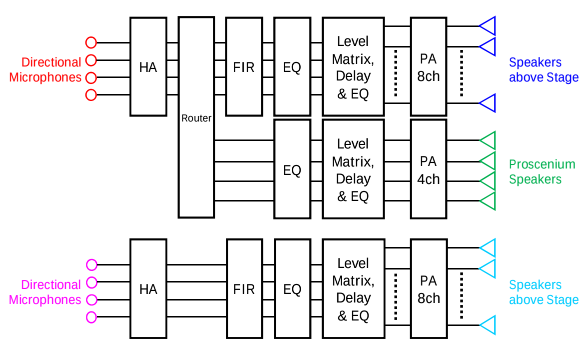

Fig. 5 Block diagram of System B.

5. MEASUREMENT

5.1. Effectiveness of the System on Stage

Acoustic measurements were carried out to verify the effect of the systems. Fig. 6 and 7 show the measurement points in each auditorium, respectively.

The measurement results of stage support are shown in Fig. 8. For ST_{early}, which evaluates the ensemble conditions, System A showed 0.6 dB enhancement (6 points average, P1-P6) and System B 2.2 dB enhancement (4 points average, P1-P4). The results of System B surpassed the 1.6 dB enhancement effect of the simple mobile type orchestra shell that we measured. In addition, for ST_{late}, which evaluates perceived reverberance, System A showed 1.9 dB enhancement and System B 4.8 dB enhancement. These results suggest that sufficient Liveness was obtained for performers.

By design, there are some restrictions in the installation positions of microphones and loudspeakers. Because they cannot be installed near performers, early reflections cannot be provided in a given range after the direct sound arrives. Fig. 9 and 10 show the comparison of impulse response with and without the system. Based on these figures, it seems that the effect of the system can be verified about 40 ms after the direct sound arrives.

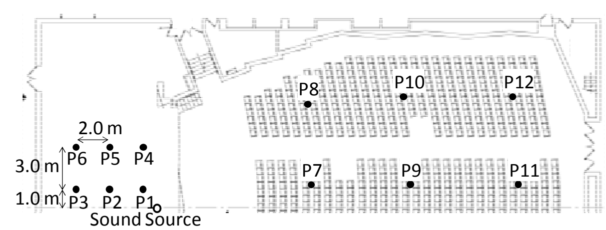

Fig. 6 Measurement point of the auditorium (System A).

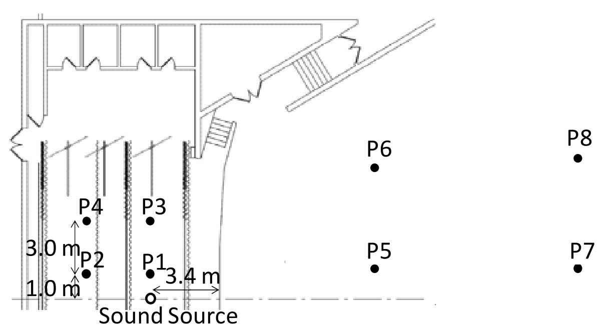

Fig. 7 Measurement point of the auditorium (System B).

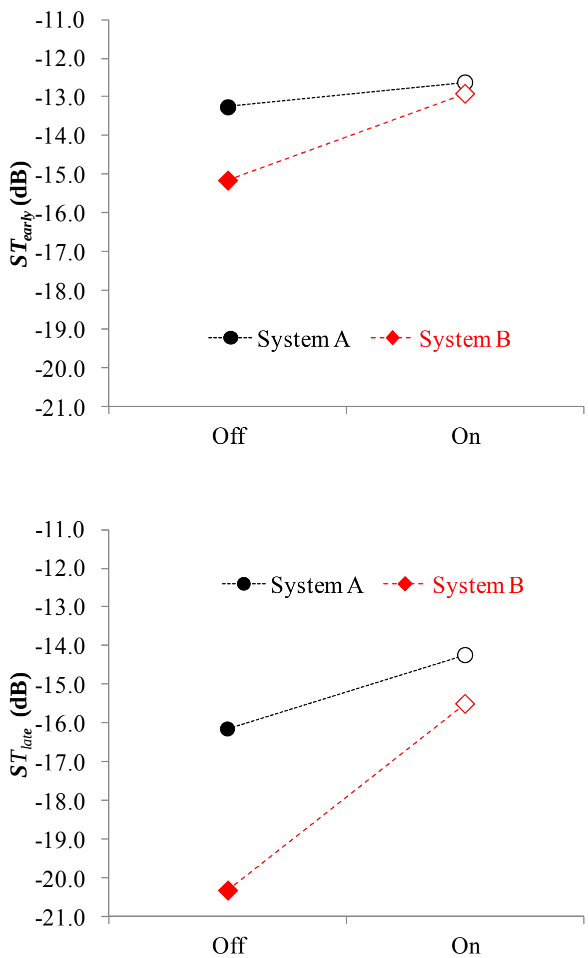

Fig. 8 Measurement results of stage support.

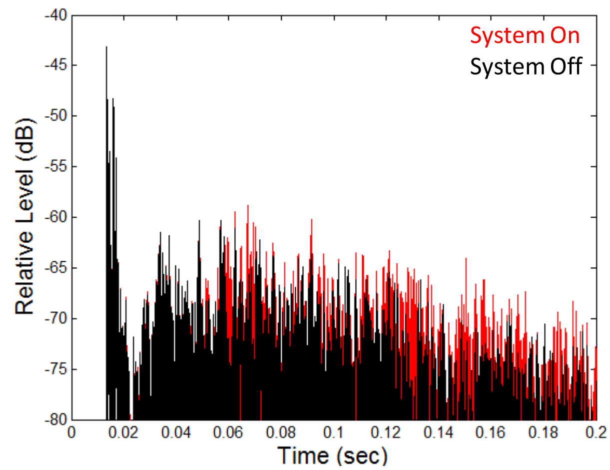

Fig. 9 Comparison of impulse response with/without system. (System A: P5, Overall)

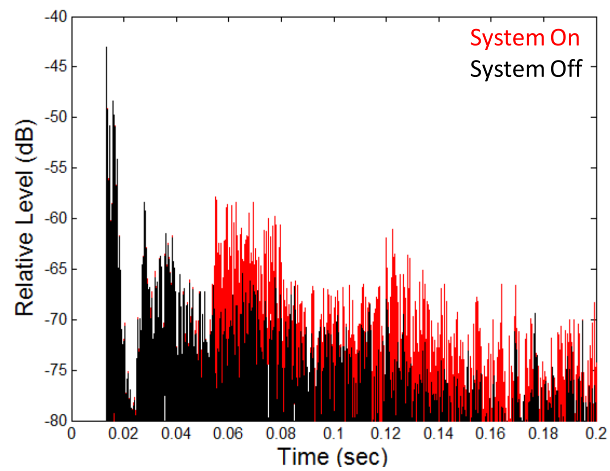

Fig. 10 Comparison of impulse response with/without system. (System B: P3, Overall)

5.2. Effectiveness of the System in the Audience Area

Fig. 11 shows the measurement results of *Strength G* with/without system. It is confirmed that each system can enhance the values throughout the auditorium. Fig. 12 shows hall-average changes in *G* with the addition of each system. In the audience area, reports show that orchestra shells produced 2 dB enhancement in *G*. The effect of the system was verified to surpass this result. Namely, System A produced 2.8 dB enhancement and System B 2.2 dB enhancement.

For reference, in order to confirm the increase of early reflection in the audience area, it is calculated G_0^{80} value and the hall-average changes in the value are shown in Fig. 13. It is confirmed the value is increased more than 1 dB in both systems. The effect of the system was verified to match the objective of the system.

In terms of *RT*, reports show that orchestra shells resulted in about 0.1 second change. Fig. 14 shows the hall-average changes in the value. The effect of the system was verified to be about the same. Namely, System A resulted in 0.12 second change and System B 0.01 second change.

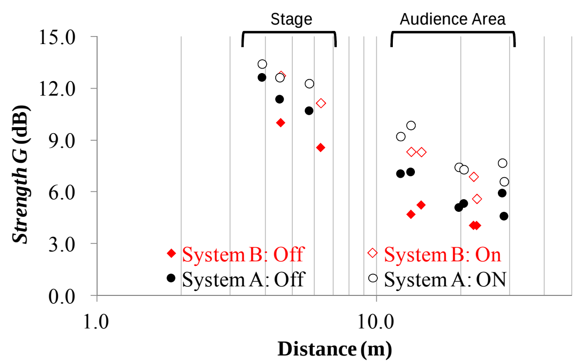

Fig. 11 Measurement results of *Strength G*.

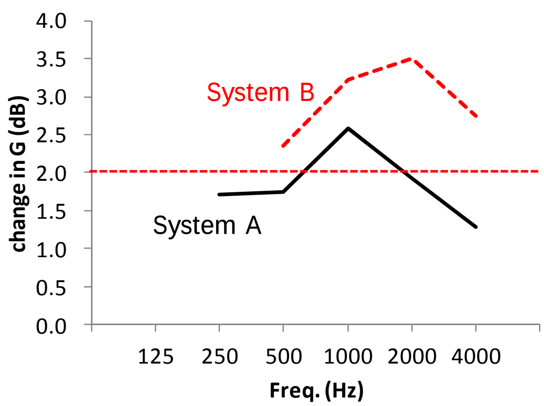

Fig. 12 Hall-average changes in total relative level (*G*) values with the addition of the system.

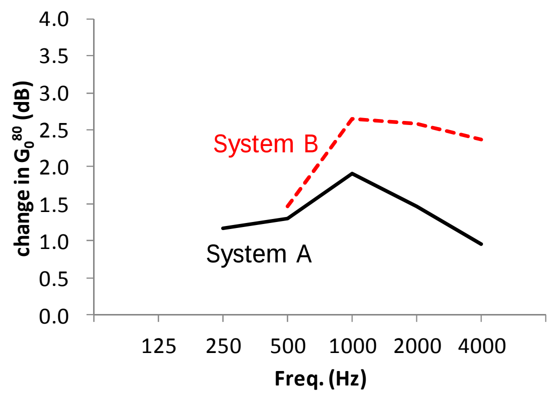

Fig. 13 Hall-average changes in early arriving relative level (G_0^{80}) values with the addition of the system.

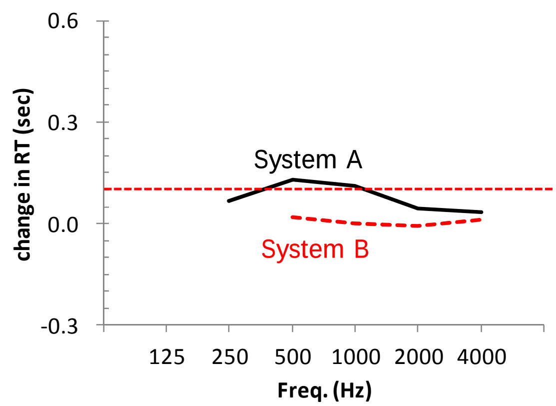

Fig. 14 Hall-average changes in reverberation time (*RT*) values with the addition of the system.

6. CONCLUSIONS AND FUTURE WORK

This paper introduced examples of the implementation of the Electronic Shell acoustic enhancement system in multi-purpose halls. The Electronic Shell system uses electro-acoustics as an alternative to simple mobile type orchestra shells. In buildings that are being modified, space limitations often make it difficult even for a simple mobile type shell to be utilized. Moreover, there are often requests to be able to change the sound field conditions in a series of events, and we believe that this system, being able to change the sound field with a single button, is extremely effective. On the other hand, to ensure system stability, installed positions of the microphones and loudspeakers should be fixed. It may be difficult to permanently fix such equipment due to the nature of multi-purpose halls, and the possibility that structural conditions around microphones and loudspeakers may be modified to a great extent is also concern. Adjustments are performed by raising all curtains which results in the most unstable feedback condition. To effectively use this system, appropriate consensus must be obtained in the planning stage.

Regarding the spatial sound structure and the time domain characteristics between simple mobile type shell and the Electronic Shell system, there are differences since the mobile type shell mainly takes care of lateral reflections; on the other hand, the Electronic Shell system takes care of overhead reflections, and it cannot provide early reflections before 40 ms after the direct sound arrives. Moreover the objective improvement of the system should be assessed subjectively by performers. The relationship between the differences in physical features and the subjective improvement of the musical performance needs to be clarified in the future.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

[1] W. J. Cavanaugh and J. A. Wilkes, Architectural Acoustics, John Wiley & Sons, Inc., 173-174 (1999)

[2] J. S. Bradley, "Some Effects of Orchestra Shells," in Acoust. Soc. Am, 100, 889-898 (1996)

[3] H. Miyazaki, T. Watanabe, S. Kishinaga and F. Kawakami, "Active Field Control (AFC)―Reverberation Enhancement System Using Acoustical Feedback Control," in Proc. of AES 115th Convention (2003)

[4] T. Watanabe and M. Ikeda, "Various Applications of Active Field Control," in Proc. of AES 134th Convention (2013)