Acoustical Renovation Using Active Field Control in Preserving an Historical Auditorium

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Abstract

Osaka Central Public Hall is treasured as an extremely important historical building in Japan. A preservation/reconstruction plan based on restoring it to its original form was implemented 80 years after its initial construction. This paper describes the concept, structure, and measurement results of the Active Field Control (AFC) system that was used to reconstruct the large assembly hall, the core of the facility, but an acoustically dead space not suited for music performances, allowing it to be used as a concert hall while preserving the original design.

1. Introduction

This auditorium, completed in 1918 with luxurious exterior and interior designs, is considered to be an extremely important historical building in Japan. Structural reinforcement to preserve its appearance and to strengthen its seismic resistance, as well as functional improvements to preserve and use the interior, were planned and implemented with the aim of restoring it to its original form 80 years after its initial construction. A live sound field was planned to allow the large assembly hall to be used as a classical concert hall, even though the core of the facility used to be a space with a dead sound field, with its use limited to lectures, ceremonies, movie viewing, etc.

Figure 1 shows a plan and section of the facility and the dimensions of the large assembly hall are given in table 1.

Table 1: Dimensions of the large assembly hall

Capacity (N)	1,161 seats
Volume (V)	8,645 m^3
Surface (S)	4,332 m^2
V/S	2.00 m
V/N	7.4

2. Concept of AFC

In order to allow the existing dog-house shape to be used for classical concert performances, a one-room shape was realized to allow the performers and audience to feel as one, without affecting the curtain equipment within the stage, by architecturally providing running reflector panels within the stage as well as a new apron stage.

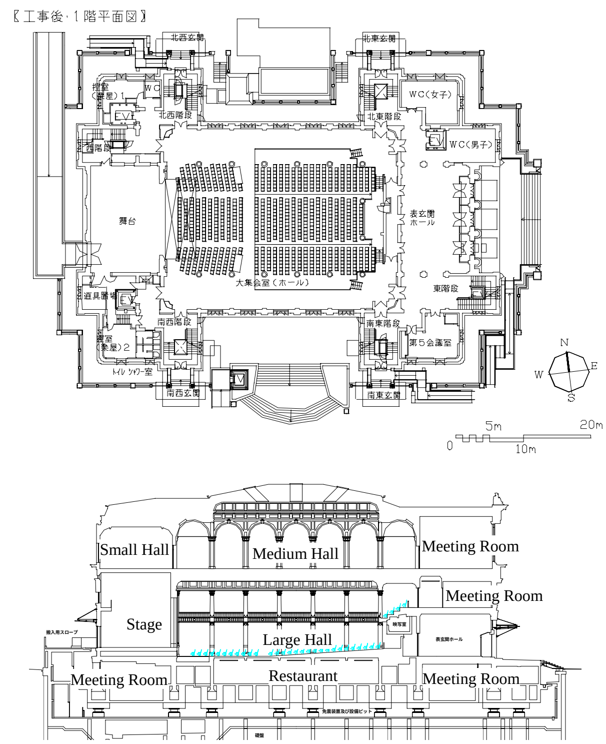


Figure 1: Plan and section of the facility

The AFC system is composed of two sections: A) an early reflection control section to compensate for the excessive room width; and B) a reverberation control section to support reverberation throughout the entire room.

2.1. What is AFC?

Technology for controlling sound fields by electro-acoustic means is often called Active Field Control, AFC. The technical field of AFC is usually classified into three categories as shown in table 2. According to this classification, the expression “AFC for auditorium” refers to “Assistance of Sound Field (A-SF)” in this table. The term AFC is hereinafter used to refer to the Yamaha version of A-SF technology.

AFC has been under development at Yamaha for more than fifteen years and installed in approximately 60 venues in Japan to date. AFC controls acoustical conditions based on the existing room conditions by utilizing the acoustical feedback of a system actively.

The AFC system is used to improve auditory impressions such as reverberance, loudness by enhancement of reverberation and sound pressure level. It is used to improve spaciousness by enhancement of early reflections. And it improves undesirable acoustic conditions such as under-balcony sound, stage acoustics.

AFC is characterized by the following features: 1) Re-creation of natural reverberation based on the physical conditions in the existing room by means of acoustical feedback control; 2) a wide range of controllability using FIR filters; 3) effectiveness independent of source and receiver positions in the room; 4) stability against howling effects using time varying control; and 5) ease of operation.

Table 2: Categories of sound field control systems

Categories		Definition
A-SF	**Assistance of Sound Field**	**Control of room acoustic conditions based on existing room conditions**
P-SF	Production of Sound Field	Production of spatial sound effects, mainly for theaters, movies, etc.
S-SF	Synthesis of Sound Field	Synthesis of requested conditions in an anechoic or highly absorbent room

2.2. Controlling acoustical effect of room shape

In early reflection control section, sound signals collected by microphones placed near the sound sources on the stage are convolved by an FIR filter, and the simulated lateral reflected sound is generated from an “Image Wall.” In reverberation control section, sound signals collected by microphones placed at the ceiling of the audience area are broadcasted into the hall through loudspeakers installed in the ceiling and chandeliers. The architectural design is such that the speakers cannot be seen. Figure 2 shows the configuration of the AFC system.

2.3. Creating an Image Wall

Early reflection control section acoustically realized a shape based on the image of a shoe–box type concert hall by producing a simulated wall using the projection of the side balcony as a boundary at the first-floor gallery sidewall. Figure 3 shows the concept of the Image Wall.

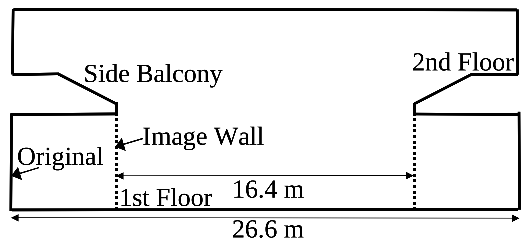
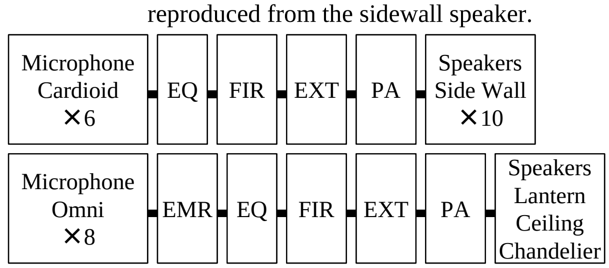


Figure 3: Concept of the Image Wall

1) We simulate an echo diagram using the original model.
2) Same as improved model. In this simulation, the receiving points are located in front of each sidewall speaker.
3) At each point, we pick up the difference between the responses of the two models (Figure 4).
4) The data is convolved using a 56-tap FIR filter.
5) The sound reaching each microphone is convolved using the FIR filter and reproduced from the sidewall speaker.



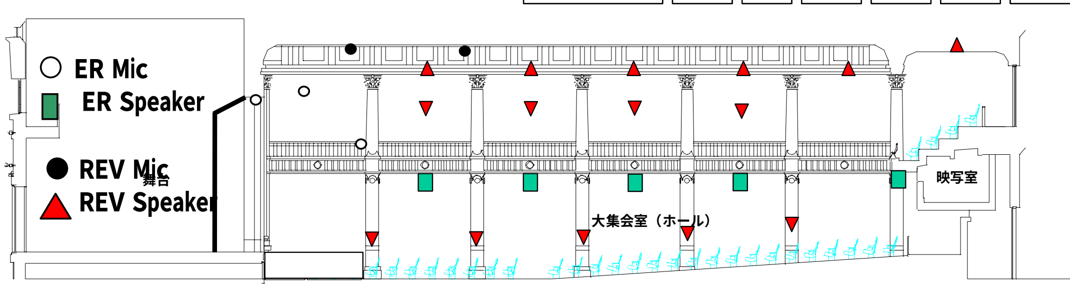


Figure 2: AFC system configuration

3. Measurement results and validity of controlling the room shape

3.1. Reverberation results

Figure 5 shows the results for the reverberation time measurements. Using AFC, the reverberation time in the unoccupied condition can be increased from 1.4 sec to 2.2 sec at 500 Hz, so that the optimum acoustics for classical music are realized in the relatively dead original space.

3.2. Validity of controlling the room shape

In order to evaluate the control of the acoustical effect of the room shape, we measured the value of the center time, ts, under the conditions shown in figure 6. ts is defined by Equation (1):

$$ts = \frac{\int_0^{\infty} t * p^2(t)dt}{\int_0^{\infty} p^2(t)dt} \qquad (1)$$

p(t) : sound pressure

t : seconds

Since the value of ts is independent of the direct sound, we can calculate the effect of early reflection, taking into account the fact that ts correlates with the distance from the acoustical barrier.

As shown in figure 7, the value of ts measured at the points near the reflected wall tends to be smaller than at the center points, because of the effect of reflection from the wall. Meanwhile, in the auditorium, when the sound source is located on the stage, the value of ts measured in the audience area increases as the distance from the source point increases.

Therefore the value of ts decreases when it gets closer to the wall, and increases when it gets further away.

Figure 8 shows that with the AFC system, the value of ts decreases when it gets closer to the Image Wall. We can control the room shape using the AFC system.

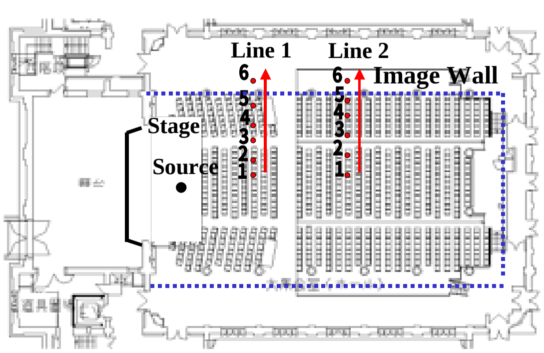


Figure 6: Schematic arrangement for measurement

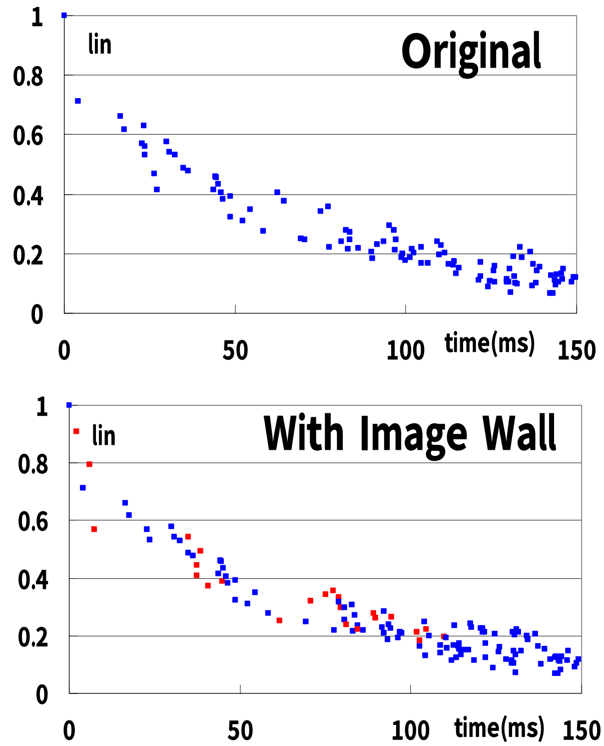


Figure 4: Example of simulation results

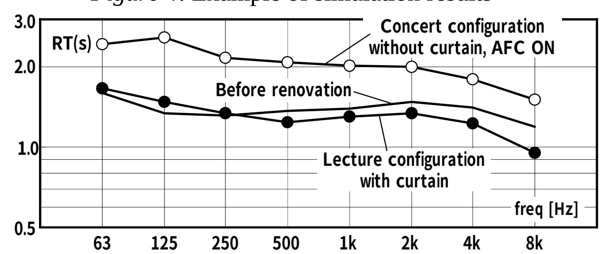


Figure 5: T60 measurement results (unoccupied)

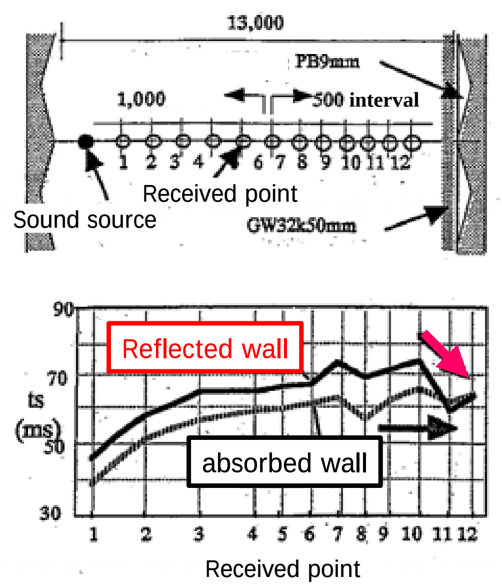


Figure 7: Example of ts measurement

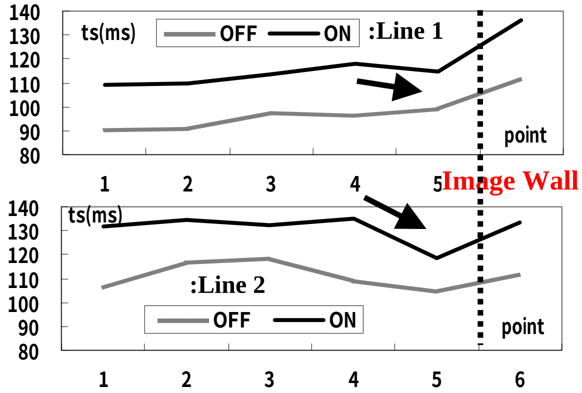


Figure 8: Results of ts measurement

4. Conclusion

It proved possible to modify the acoustical characteristics of the hall for multi-purpose use, and the effect on the existing design was minimized by using the AFC system. The differences in the variable range of the reverberation time and control of the acoustical effects of the room shape were confirmed quantitatively, and the facility was transformed into a hall for classical concerts which provides sound that feels acoustically natural.

5. References

[1] Kawakami, F. and Shimizu, Y., "Active Field Control in Auditoria", *Applied Acoustics*, vol. 31:pp.45-47, 1990.

[2] Miyazaki, H. et al., "Active Field Control", AES 115th Convention, New York, 2003.