Basic study on improvement of stage acoustics by active method

Takuma MATSUO[1]; Takane TERASHIMA[2]; Ayumi ISHIKAWA[3]

[1,2,3] Mie University, Japan

ABSTRACT

The purpose of this study is to optimize sound field for players on stage of concert hall by active method. Optimization of sound field for players is difficult because there is unevenness in sound field even on narrow stage and also difference of preference among players by musical instrument or personality. This study is to investigate fundamentally into a means to solve this problem by controlling sound field of the player neighborhood locally by superimposing sound fields actively.

In this report, the effect of superimposition was discussed by comparing ST_{Early} of original sound field and feedback sound field that was convoluted with specific sound field data (impulse response).

Keywords: Stage acoustics, Active, Support I-INCE Classification of Subjects Number(s): 51.1

1. INTRODUCTION

In acoustic design of concert hall, it has been main point and regarded as important to optimize acoustics of audience area for a long time. Recently, acoustics of stage area of hall, optimal acoustic design for players has become weighty with research development in this region, but enough data which clarifies relationship of player's subjectivity and physical quantity have not been obtained yet. And even in narrow space of stage, sound fields in stage area vary by place and place, and desirable acoustical condition changes by player with various musical instrument and location. Thus, optimal acoustic design in stage area by architectural passive approach is so difficult.

Although the ultimate purpose of this study is to offer the optimal performance sound environment for player in stage area, in this paper, it is assumed to be important that local sound field in the neighborhood of player could be controlled regardless of true value of the optimal acoustical conditions, and how to solve the above-mentioned problem using sound feedback active system adding architectural passive approach is examined. It is assumed that for end stage type hall, in which sound fields of stage and audience area can be considered as independent acoustically, there is little influence of the feedback sound in stage area upon the sound field in audience area because local sound field will be controlled by a plane wave loudspeaker in near future. When the player is performing taking into consideration the sound field of the whole hall including audience area, this active method could not be suitable, but it would be possible that it works when effective in communication between players in ensemble performance.

In this paper, changes of acoustic properties of sound fields on the real stage were measured when sound field by reflection from stage enclosure were superimposed with feedback sound field, and the influences by architectural conditions and properties of feedback sound field were discussed.

2. EXPERIMENT

2.1 Settings

As shown in Figure 1, two circuits of experiment were constructed, which include two personal computers, super-directional microphone, omnidirectional microphone, dodecahedron loudspeaker and general-purpose loudspeaker.

In Circuit 1, TSP signal is generated from a personal computer (PC 1) and reproduced through

[1] matsuo@e.arch.mie-u.ac.jp
[2] tera@arch.mie-u.ac.jp
[3] ayumi@e.arch.mie-u.ac.jp

dodecahedron loudspeaker (sound source), and sound field at receiver position is recorded through omnidirectional microphone (mic 1). In Circuit 2, TSP signal from sound source, which includes little reflection, is caught by super-directional microphone (mic 2) and convoluted with impulse response data in real time on a personal computer (PC 2). Convoluted sound is fed back through general-purpose loudspeaker (feedback LS) to the local area near receiver position and sound fields are superimposed. This superimposed sound field is recorded through omnidirectional microphone, and its acoustic properties are analyzed on PC 1.

The distance between sound source and mic 1 (receiver position) is 1.0 m and each height is 1.5 m above floor. Mic 2 is located 1.0 m from sound source and directed to sound source, but not to catch feedback sound from feedback LS. Feedback LS is located in front of receiver position, 0.3 m above floor and directed to receiver position (see Picture 1).

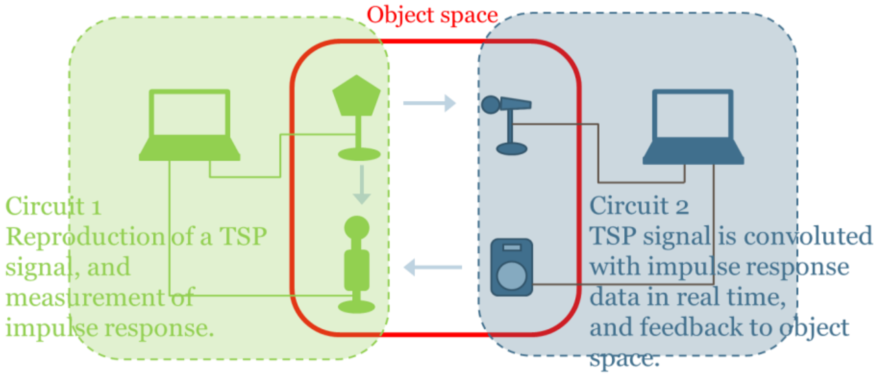


Figure 1- Circuits of experiment


Picture 1 – Experimental equipment

2.2 Conditions

In the experiment, measurements were carried out by changing three parameters, 1- receiver position on stage, 2 - stage ceiling height and 3 - impulse response data used for convolution. Figure 2 and 3 show a stage plan and section views of the hall (Sansui Hall of Mie University) used in the experiment. Eight points of measurements are plotted as “a”~“i” in these figures. Stage ceiling height was changed at three levels; 5.0 m (“L”), 7.5 m (“H”) and no ceiling (“N”), see Picture 2. Table 1 shows the acoustic properties of six impulse response data (IR) using for convolution. These were recorded previously at several positions on the stage of this hall. Measurements were carried out in a total of 168 conditions, which include the cases without convolution (i.e. no feedback condition).

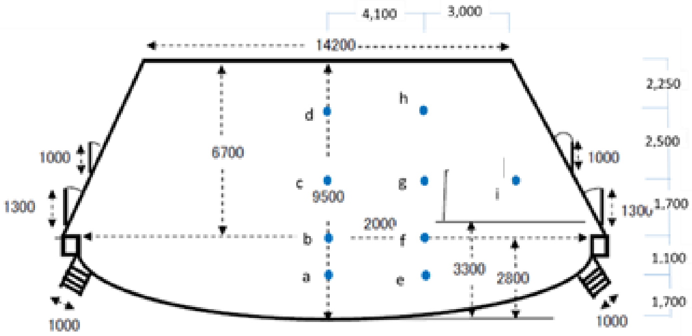


Figure 2 - Stage plan

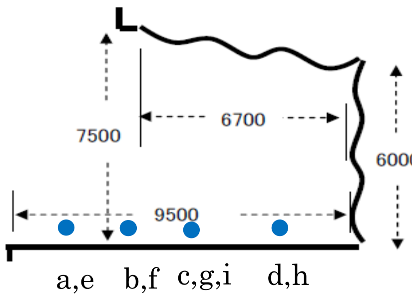


Figure 3 - Stage section


Level “L” Level “H” Level “N”

Picture 2 – Difference in ceiling height

Table 1 - Acoustic properties of IR used for convolution in feedback sound

Notation	ST_{Early}[dB]	T_{sub}[s]	T_{30}[s]	EDT[s]	C_{80}[dB]	G[dB]
0	No Convolution (No Feedback)					
1	-7.8	0.87	1.30	0.26	16.03	2.85
2	-9.7	0.81	1.24	0.16	16.10	2.61
3	-12.4	1.21	1.35	0.08	15.05	2.88
4	-13.8	1.04	1.29	0.08	17.75	2.92
5	-16.5	0.92	1.26	0.20	17.98	3.04
6	-18.6	0.92	1.42	0.08	19.39	2.24

2.3 Evaluation Index

In this study, ST_{Early} (Stage Support, Early) [dB] is used as an evaluation index. ST_{Early} is advocated as an evaluation index of the performance environment on a stage, and shows the ratio of effective reflected sound energy to direct sound energy. Next equation shows the definition of ST_{Early} (t: time in millisecond, $p(t)$: sound pressure).

$$\mathrm{ST_{Early}} = 10\log_{10}\frac{\int_{20}^{100} p^2(t)dt}{\int_{0}^{10} p^2(t)\,dt}$$

3. RESULT AND DISCUSSION

Figure 4 shows the measured ST_{Early} values of no feedback condition in each measuring point for every ceiling height. It is common in all cases that ST_{Early} value of the condition without ceiling (N) is the lowest among the same points. However, any relationship between Level ”L” and “H” cannot be seen.

Table 2 shows the distance from sound source to nearest reflective surface for each condition. The measuring point, in which ST_{Early} value of “L” is larger than “H”, is “d”, “e”, “g”, “h” and “i”. These points are a little apart from stage center and have walls immediately close. The point, in which ST_{Early} value of “L” is smaller than “H”, is “a” and “b”. These points are near the front end of center seat area, and considerably distant from the sidewall. And the point, in which ST_{Early} value of “L” is equal to “H”, is “c” and “f”.

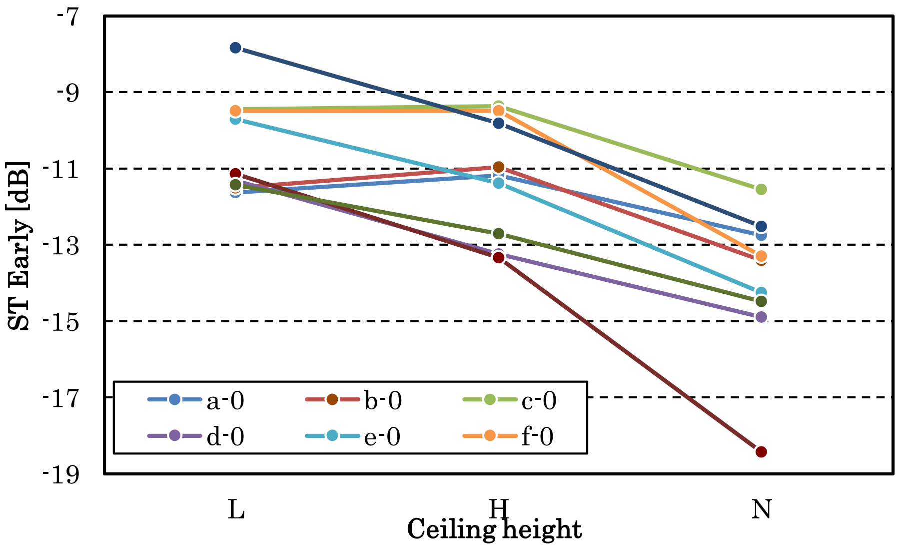


Figure 4 - ST_{Early} values in the conditions without feedback

Table 2 - Distance from sound source to the nearest reflective surface

DISTANCE (mm)	MEASUREMENT CONDITION
7,800	a H-N
7,500	e H-N
6,700	b H-N, f H-N
5,200	a L, e L
5,000	b L, f L
4,750	c L-H-N, g L-H-N
2,250	d L-H-N, h L-H-N, i L-H-N

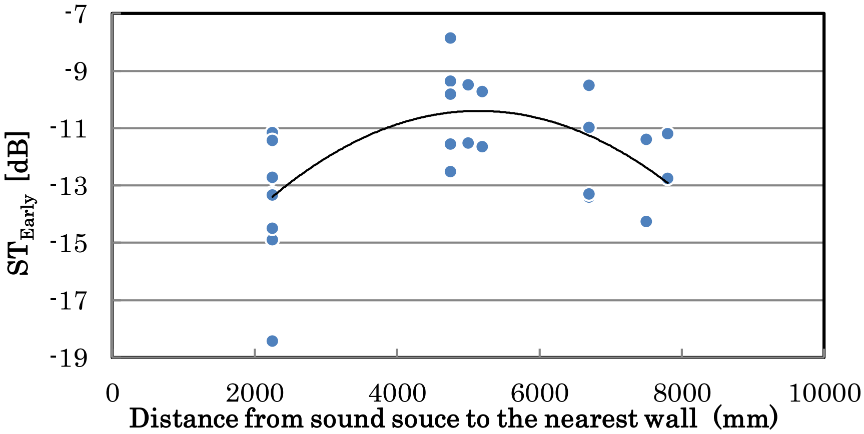


Figure 5 - Relationship of ST_{Early} and distance from sound source to the nearest wall

Figure 5 shows the relationship between ST_{Early} values and the distance from sound source to the nearest wall for every measuring point. The values of ST_{Early} seem to be distributed with the peak at 4,750 mm. The points with 4,750mm distance are "c" and "g", and these are central area of stage.

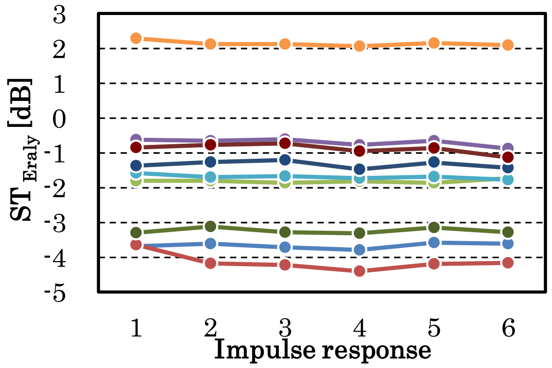


Figure 7 - IR and ST_{Early} in case of Level "L"

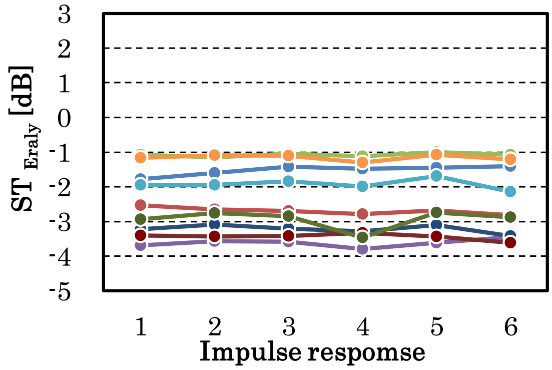
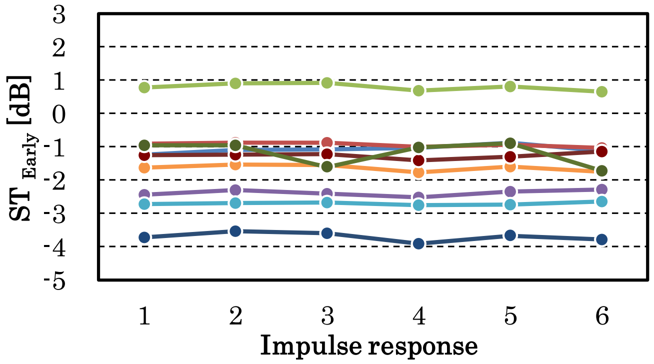
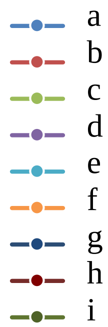


Figure 6 - IR and ST_{Early} in case of Level "H"





Legend

Figure 8 - IR and ST_{Early} in case of Level "N"

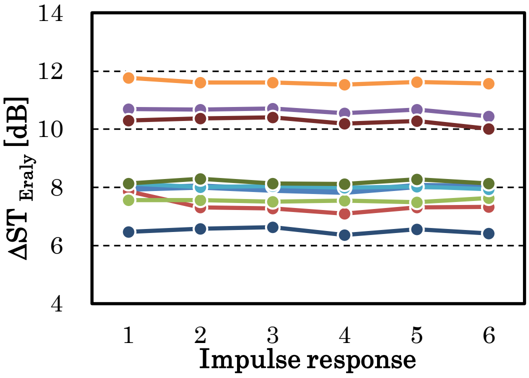


Figure 10 - IR and ΔST_{Early} in case of Level "L"

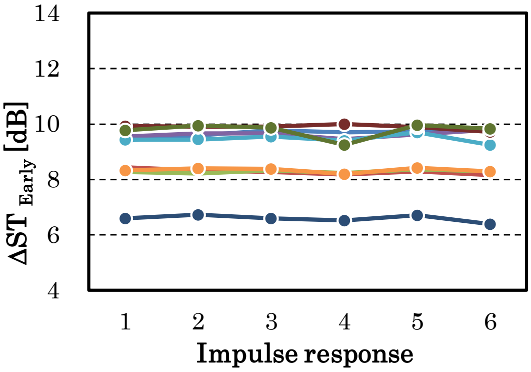


Figure 9 - IR and ΔST_{Early} in case of Level "H"

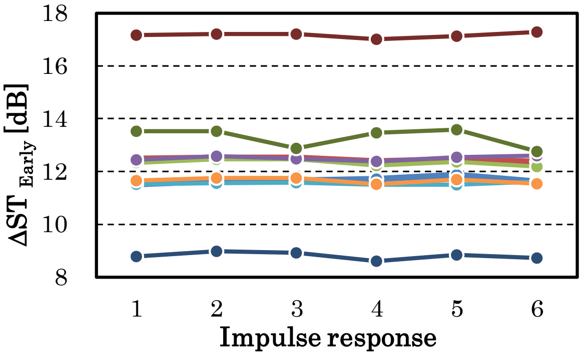


Figure 11 - IR and ΔST_{Early} in case of Level "N"

Figure 6, 7, and 8 show the change of ST_{Early} values by ceiling height and the IR used for convolution for every measuring point. One can see difference of ST_{Early} values by ceiling height and measuring point, but it turns out that the difference by IR is quite small.

Figure 9, 10, and 11 show the change of ST_{Early} value difference from no feedback condition (ΔST_{Early}) by ceiling height and the IR used for convolution for every measuring point. In case of Level "N", ΔST_{Early} values are larger than other case on the whole.

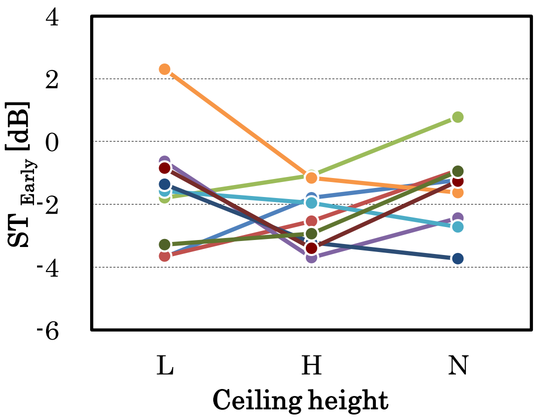


Figure 12 - Ceiling height and point (IR-1)

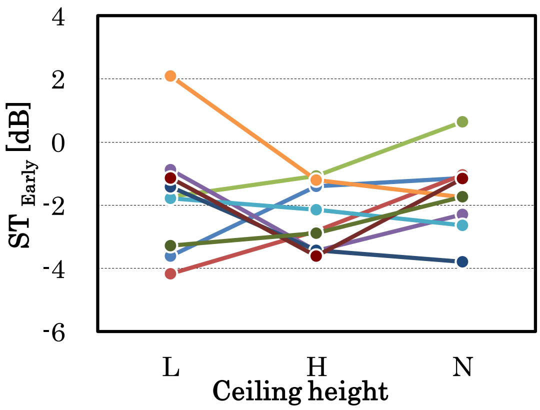


Figure 13 - Ceiling height and point (IR-6)

Figure 12 and 13 show the change of ST_{Early} values by measuring position of measurement and ceiling height, in the case of convolution with IR-1 and IR-6. In these figures, one can see the tendency that distribution width by measuring points is smallest at ceiling height "H", on the contrary that is large at ceiling height "L".

4. CONCLUSIONS

In this study, fundamental examination was discussed about a method of improving stage acoustics for players, which operates ST_{Early} value of stage by superimposing sound fields actively. In real hall stage, experiment, in which original sound field was changed by feedback sound and the change of ST_{Early} value was measured, was carried out. Three parameters of experimental condition were examined, measuring point location, ceiling height on the stage and feedback sound effect.

As a result, it is found that ST_{Early} value on the stage could be influenced by point location and ceiling height, especially the direction/angle of reflective surface, which feedback loudspeaker is just opposite. On the other hand, ST_{Early} was little influenced by difference of IR convoluted in this experiment.

As a future task, more detail of influence of reflective surface on the feedback will be examined. And specification of active method would be investigated in near future.

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