Applied Acoustics 139 (2018) 101–112

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Study on acoustic improvements by sound-absorbing panels and acoustical quality assessment of teleconference systems

Takafumi Shimizu[a,*], Hiroshi Onaga[b]

[a] Central Research Laboratory, Daiwa House Industry Co., Ltd., Japan
[b] Dept. of Architecture, Faculty of Architecture, Kindai University, Japan

ARTICLE INFO

Keywords:
Teleconference system
Tele-education system
Impulse response
STI
Reverberation time
Clarity (C_{50})
Intelligibility
Listening difficulty ratings

ABSTRACT

With the development of information and communications technology, conferences and remote education using teleconference systems have become common. When a teleconference system is used, the sound heard in a receiving room includes the acoustic characteristics of both the utterance and receiving rooms, in addition to the characteristics of the transmission via the teleconference system and Internet. Even today, when the digital technology is widely used, quality problems related to sound transmission remain; in particular, the influence of the reverberation of the conference room causes deterioration of the sound quality. Studies aiming to improve the quality of the signal transmission have been conducted; however, there are no acoustic countermeasure methods considering the acoustic characteristics of the two rooms connected by a teleconference system and performing the sound quality evaluation. In this study, focusing on a teleconference system sharing video and audio between two separate rooms, we evaluated the improvement in the sound transmission performance due to the addition of sound absorption to the conference room by examining the correspondence between the subjective assessment results and acoustical physical indexes. Additionally, the acoustical physical indexes that allow evaluating the quality of the sound transmitted via the teleconference system were also examined by comparing with the result of a subjective assessment. Intelligibility tests were conducted, listening difficulty ratings were evaluated, and the impulse response, STI, Clarity (C_{50}), and reverberation time were measured in an actual teleconference system. We observed that, before the addition of sound absorption, the sound was difficult to listen to due to the acoustic characteristics of both of the utterance and receiving rooms. However, by suppressing reverberation in both the utterance and receiving rooms by using sound-absorbing panels, the difficulties in listening was improved. By examination of the correspondence between the subjective assessment results and acoustical physical indexes, we proved that STI and Clarity (C_{50}) are highly correlated with intelligibility. On the other hand, reverberation time was found to be uncorrelated with the intelligibility of the rooms of teleconference systems.

1. Introduction

With the development of information and communications technology in recent years, remote conferences and remote education using teleconference systems have become common. Unlike a typical conference held in a single room, the sound heard in the receiving room of a teleconference system includes the acoustic characteristics of both the utterance and receiving rooms, in addition to the transmission characteristics of the teleconference system and Internet. As a result, the ease of listening is reduced. Furthermore, it is of note that difficulty in listening at conferences causes fatigue that increases with time.

Numerous studies on the transmission characteristics of communication signals and their evaluation have been carried out, and it has become apparent that these characteristics influence the sound quality of teleconference systems. Before the introduction of digital technology, Perkins et al. [1] reported that the main factors in lowering the speech quality are the reduction in the signal strength, the noise from the circuit itself or other interferers, and echoes, when speakers hear their own voice due to a delay in transmission. Recently, as interference from noise sources in speech signals is suppressed by the widespread use of the digital technology, signal amplification has become easier. As a result, signal strength reduction is not a serious issue anymore. However, the problems related to the sound quality in the transmission of speech remain, with the following three main factors causing deterioration in the sound quality: (i) the background noise generated by air conditioners, (ii) noise from computers and other sound sources in the

* Corresponding author at: Daiwa House Industry Co., Ltd, Central Research Laboratory, 6-6-2 Sakyo, Nara 631-0801, Japan.
E-mail address: t-shimizu@daiwahouse.jp (T. Shimizu).

https://doi.org/10.1016/j.apacoust.2018.04.021
Received 13 November 2017; Received in revised form 15 April 2018; Accepted 17 April 2018
Available online 24 April 2018

Table 1
Sound absorption levels and parameters of sound-absorbing panels.

Sound absorption level	Room A (Size: L 7.9 m × W 4.0 m × H 2.7 m) (Total surface area: 127.5 m^2, Volume: 85.3 m^3)	Room B (Size: L 4.7 m × W 3.2 m × H 2.7 m) (Total surface area: 72.7 m^2, Volume: 40.6 m^3)
Level 0	–	–
Level 1	2.94 m^2 (Type A × 6)	1.96 m^2 (Type A × 4)
Level 2	5.04 m^2 (Type A × 8)	3.92 m^2 (Type A × 8)
Level 3	7.6 m^2 (Type A × 8 + Type B × 7)	6.02 m^2 (Type A × 2 + Type C × 8)

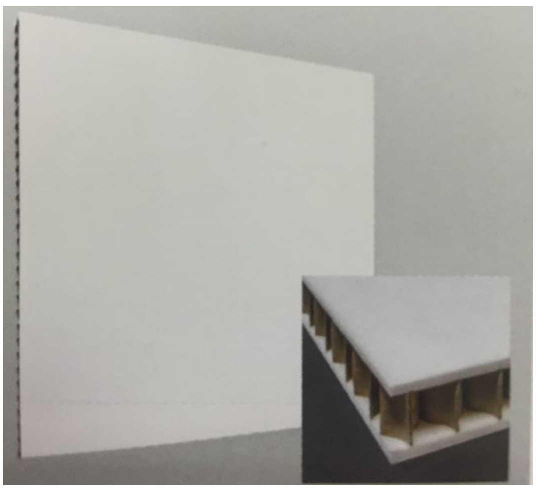

Fig. 1. Sound-absorbing panel with honeycomb paper structure.

Table 2
Type and size of the sound-absorbing panels used in the experiment.

Panel type	Size (mm)	Surface area (m^2)
A	W: 700 × H: 700 × T: 29	0.49
B	W: 600 × H: 900 × T: 29	0.54
C	W: 700 × H: 900 × T: 29	0.63

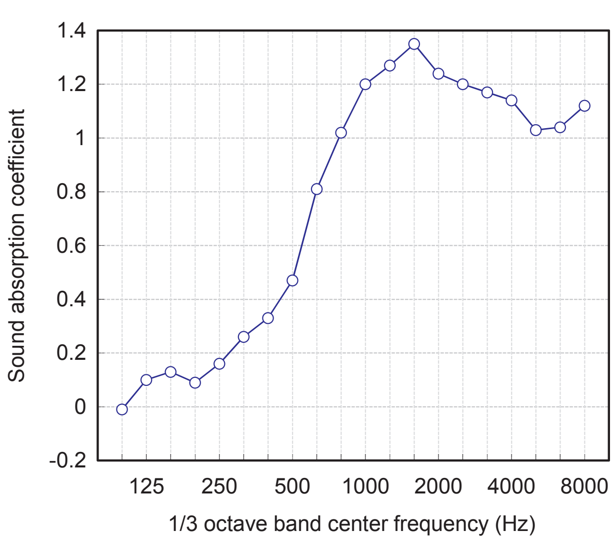

Fig. 2. Sound absorption coefficient measured with JIS A 1409.

Table 3
Measurement configurations.

Measurement No.	Utterance side			Receiving side	
	Room	Sound absorption level		Room	Sound absorption level
No. 1	A_0	Level 0	→	A_0	Level 0
No. 2	A_1	Level 1	→	A_1	Level 1
No. 3	A_2	Level 2	→	A_2	Level 2
No. 4	A_3	Level 3	→	A_3	Level 3
No. 5	A_0	Level 0	→	B_0	Level 0
No. 6	A_1	Level 1	→	B_1	Level 1
No. 7	A_2	Level 2	→	B_2	Level 2
No. 8	A_3	Level 3	→	B_3	Level 3
No. 9	A_0	Level 0	→	B_{term}	–
No. 10	A_{term}	–	→	B_0	Level 0
No. 11	A_{term}	–	→	B_{term}	–

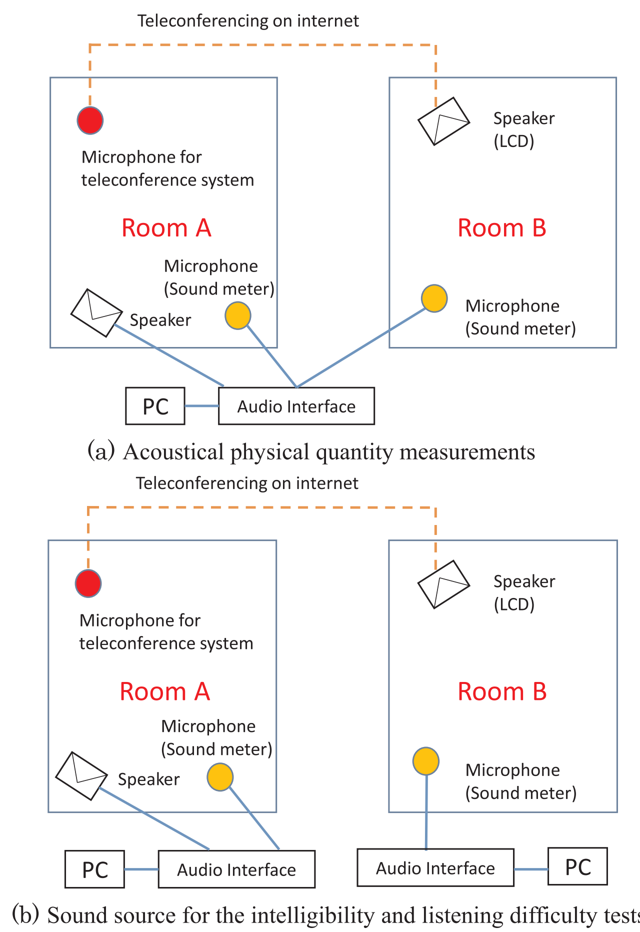

Fig. 3. Block diagrams for the measurements.

utterance and receiving rooms, and (iii) the echo formed by the sound signal returning to the utterance room via the speaker and microphone in the receiving room and the reverberation added to the transmitted speech in the utterance room and receiving rooms. Falk et al. reported that the influence of the reverberation is the most complicated aspect, and therefore, a more detailed analysis and a new objective method for sound quality evaluation are required [2,3].

On the other hand, focusing on the evaluation of the reverberation level present in the teleconference speech signal, Lima et al. evaluated the effect of the reverberation on human perception. In addition, they conducted an objective evaluation of the reverberation based on standard speech evaluation tools [4]. In a study on the transmission of speech by telecommunication, Yairi et al. evaluated and predicted the influence of architectural space and the use of a cell phone on the difficulty of listening, considering differences in telecommunication