



National Institute of Information and Communications Technology

Personal 3D Sound Field Reproduction Technique for Remote Control Using Wave Front Synthesis and Eight Directional Microphones

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Outline

- Introduction
- Diagram of proposed technique
- Experiment
 - Localization test
 - Result
- Conclusion

Introduction

- 3D sound field reproduction technique
 - Reproduce the accurate 3D sound field
 - Listeners feel the more realistic sensation
 - Application case

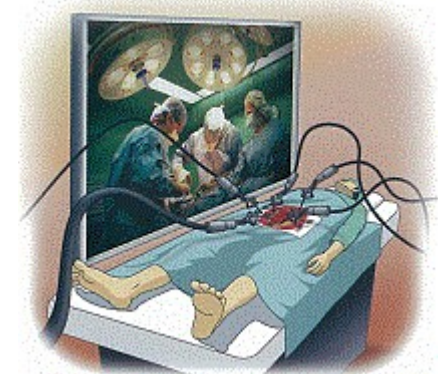
3D television



3D teleconference



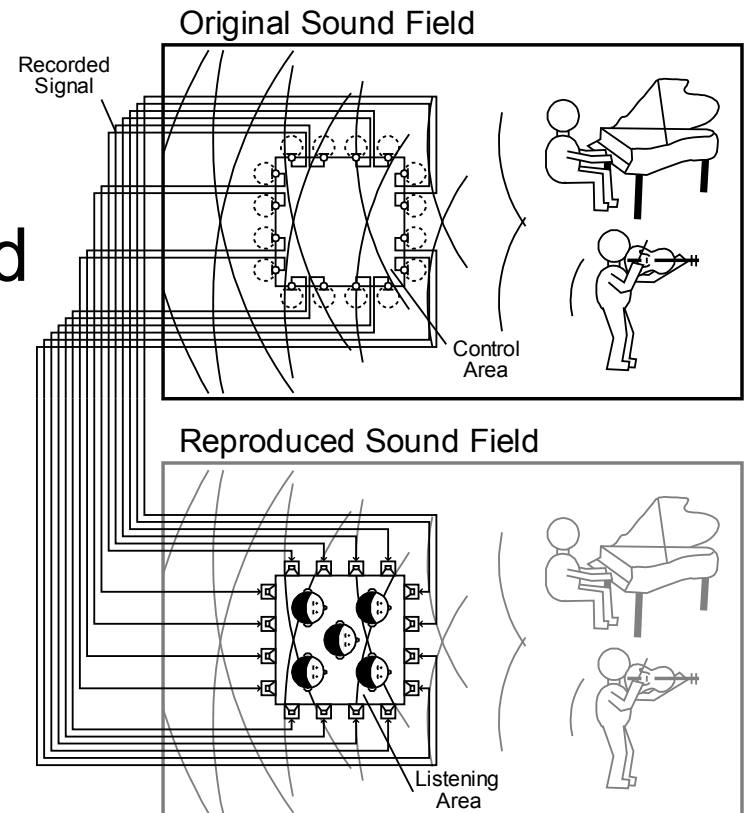
3D remote control



- For 3D remote control
 - It is preferable that the number of transmission channels is little

Wave Front Synthesis by Directional Microphones

- Original sound field
 - Sound is captured by the array of directional microphones
- Reproduced sound field
 - Sound is directly replayed by the loudspeaker array
 - Wave fronts are reproduced according to Huygens' principle
- Feature
 - Anyone can feel a 3D sound field
 - Delay does not occur by inverse filtering

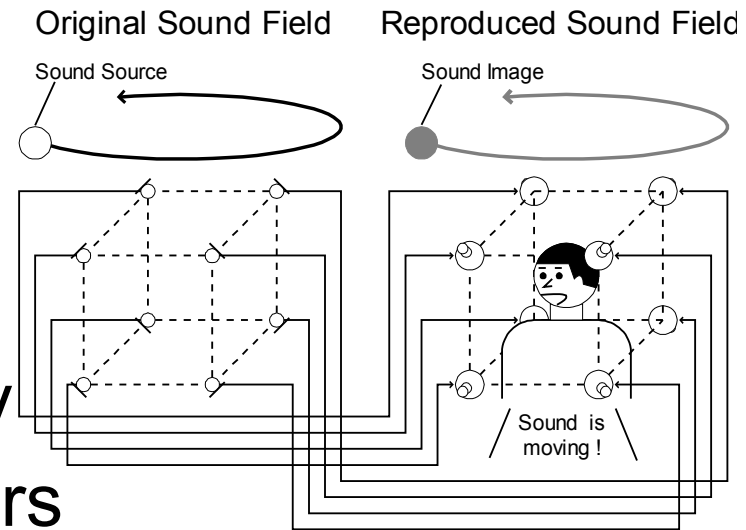


Aim of Study

- Novel 3D sound field reproduction technique is proposed
 - 8 directional microphones
 - Wave front synthesis
 - The number of transmission channels is 8
- The auditory capability of the proposed technique is evaluated
 - Localization test

Diagram of Proposed Technique

- Original sound field
 - Sound is captured by 8 directional microphones
- Reproduced sound field
 - Captured sound is directly replayed by 8 loudspeakers
 - 3D sound field is reproduced in a cubic area
- Feature
 - Listener can turn his/her head while listening to a sound
 - Loudspeakers are not visible in the listener's horizontal field of vision



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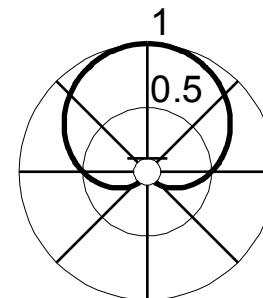
Synthesis of Captured Sound

- Multichannel signals $x_i(n)$ are synthesized on a computer

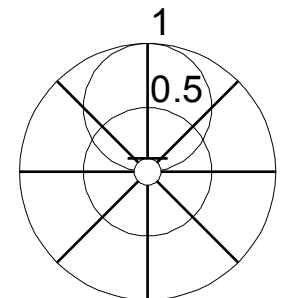
$$x_i(n) = \frac{D_i}{d_i} s \left\{ n - \text{round} \left(\frac{d_i F_s}{c} \right) \right\} \quad (i = 1 \dots 8)$$

- $s(n)$: Sound source signal
- F_s (=48 kHz): Sampling frequency
- c (=340 m/s): Sound velocity
- d_i : Distance between the sound source and microphones
- D_i : Microphone directivity

Unidirectional

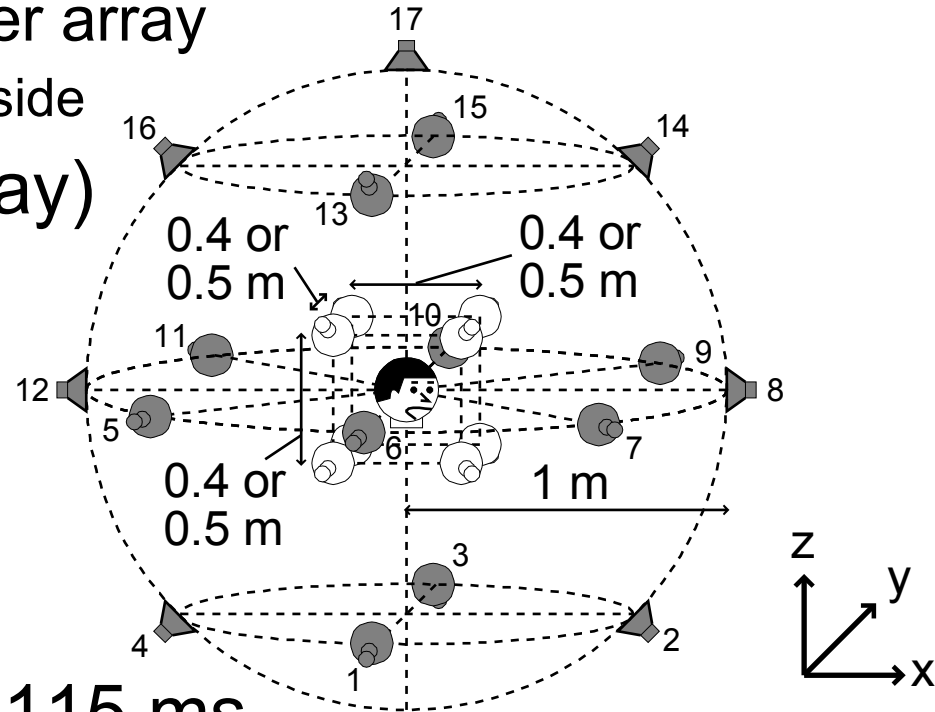


Shotgun



Experimental Environment

- 25 loudspeakers
 - 8 loudspeakers (white)
 - For cubic loudspeaker array
 - 0.4 m or 0.5 m on a side
 - 17 loudspeakers (gray)
 - For control condition
- Listening position
 - Center of a sphere
- Room conditions
 - Reverberation time: 115 ms
 - Background noise level: 20 dB(A)
 - Sound pressure level: 60 dB(A) at position



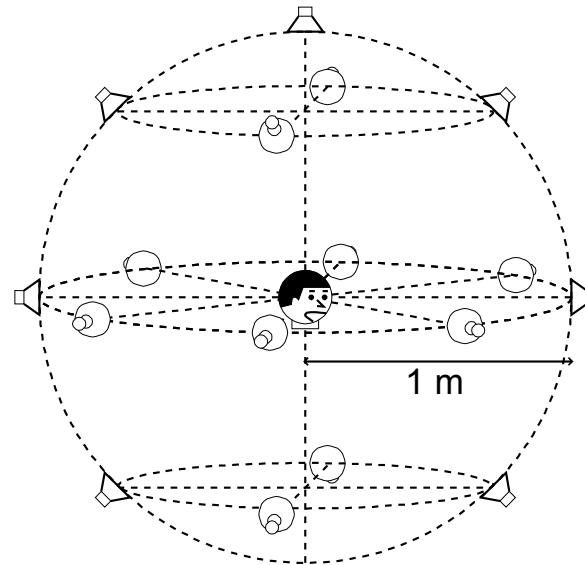
Reproduced Patterns in Localization Test

- The localized performance was compared among the four reproduced patterns

	Microphone directivity	Array size
(i)	Unidirectional	0.4 m
(ii)	Unidirectional	0.5 m
(iii)	Shotgun	0.4 m
(iv)	Shotgun	0.5 m

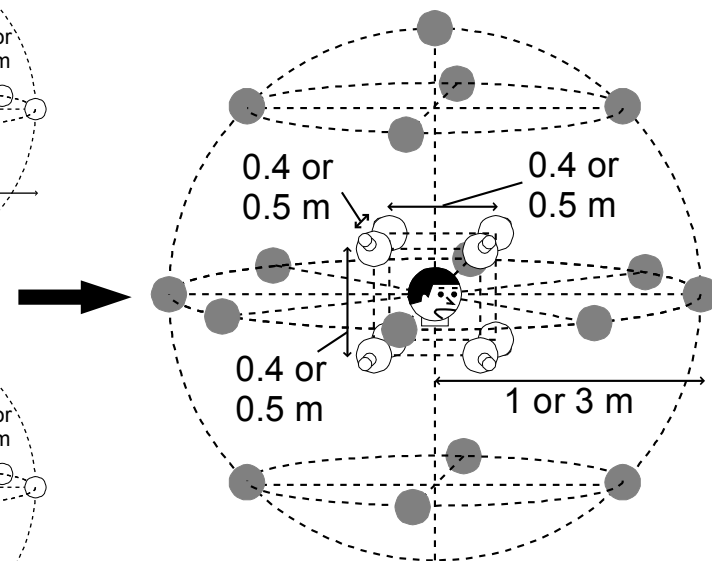
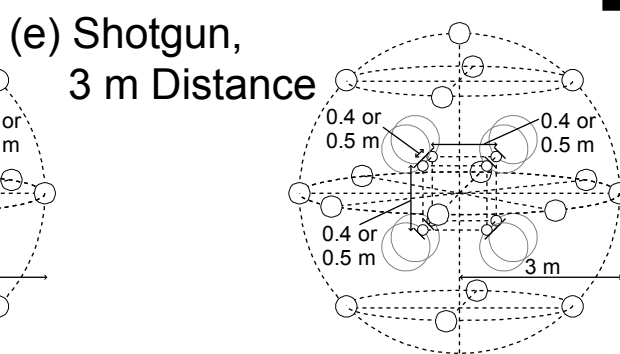
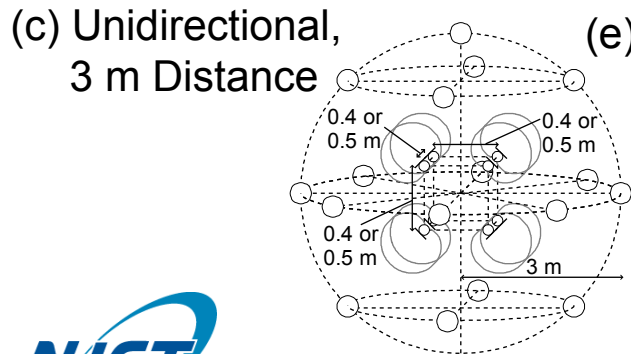
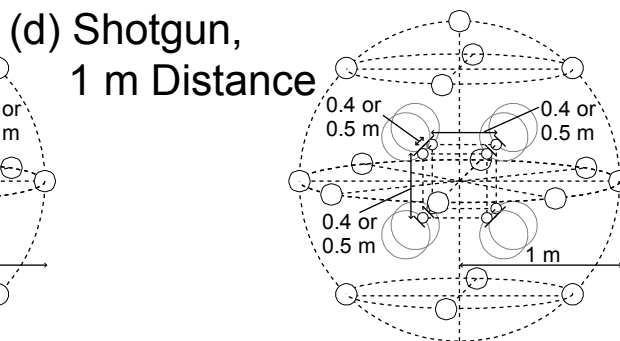
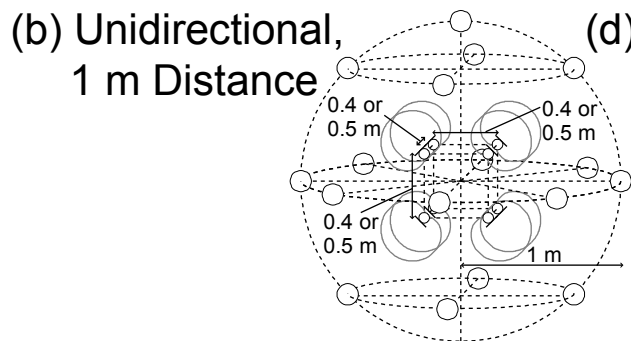
Experimental Condition

- Control condition (a)
 - Sound source signal is directly replayed from one loudspeaker selected from 17 loudspeakers
 - Listener feels that there are one sound source in the position of white loudspeakers



Experimental Condition (Cont')

- Reproduced conditions (b)-(e)
 - 8ch synthesized signals are replayed from eight loudspeakers
 - Listener feels as if there are one sound image in the position of gray circles



Experimental Design

- 10 listeners
 - 7 males
 - 3 females
- Sound source
 - White noise
 - 4 seconds

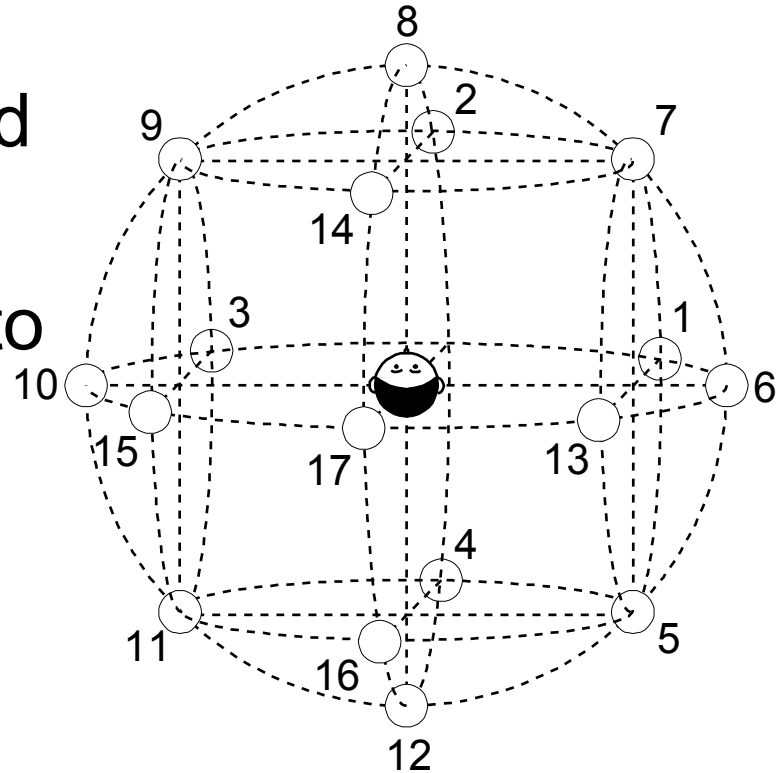
Localization Test

Session 1		Session 2			
Order...Randomized (Array size 0.4 m or 0.5 m)					
Session					
Practice (34 trials)	Main (170 trials)				
	(43)	(42)	(43)	(42)	
Trial					
Stimulus (4 s)			Answer (4 s)		

	Element	Note
Practice(34)	= 2 conditions x 17 directions	Experimental conditions (a) & (b)
Main(170)	= 5 conditions x 17 directions x 2 repetitions	Experimental conditions (a)-(e)

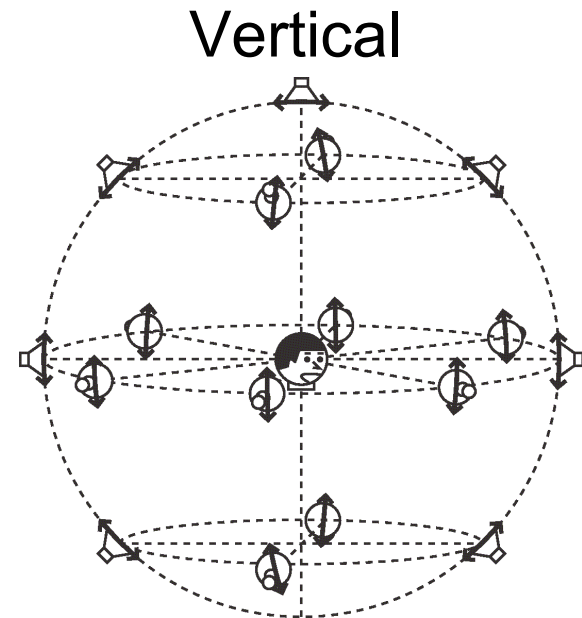
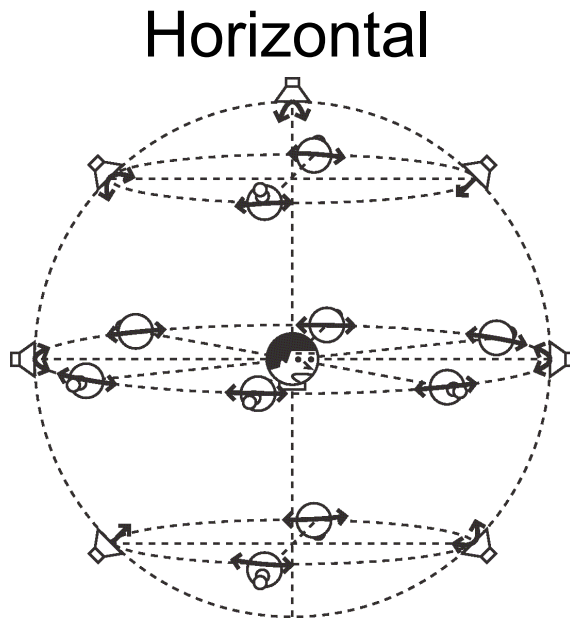
Experimental Procedure

- Instruction
 - The listener reports the perceived direction of sound
 - The listener lists the number of the direction in an answer sheet
 - The listener is allowed to turn his/her head freely while listening to the sounds



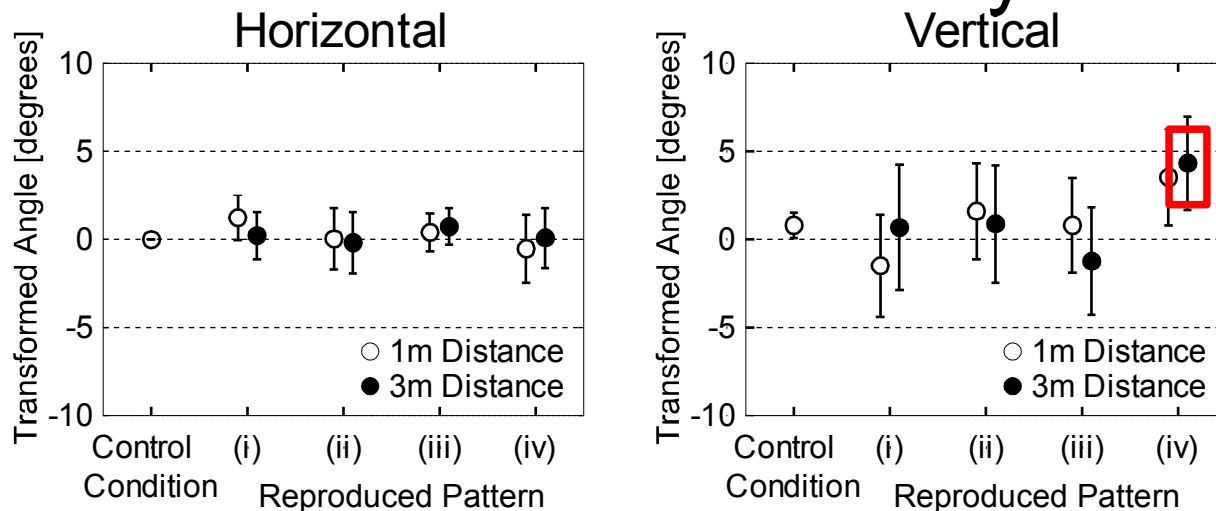
Analysis Based on Transformed Angles

- Transformation of azimuth and elevation angles
 - Horizontal angle: left-right direction
 - Vertical angle: up-down direction
 - When listener turns his/her face to the presented direction



Result of Transformed Angle Error

- There are no significant differences
 - Except 3m, (iv) in the vertical angle
- Error values are less or equal than 4.32°
 - Less than that of the difference limen in the ventriloquism effect
- Performance is enough to construct the audio-visual remote control system



Conclusion

- Personal 3D sound field reproduction technique for the remote control
 - Wave front synthesis
 - Eight directional microphones
- Evaluation of the localized performance of the proposed technique
 - Analysis based on the transformed horizontal and vertical angles
 - Localized performance of the proposed technique was enough to construct the audio-visual remote control system

Future Work

- Development of the prototype audio-visual remote control system
 - Glasses-free 3D video display technique
 - Proposed technique
- Evaluation of the effect of the developed system

