

2aPP9.

Subjective Assessment for the Number of
Channel Signals to Realize Sound Field
Based on Wavefield Synthesis

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Aim

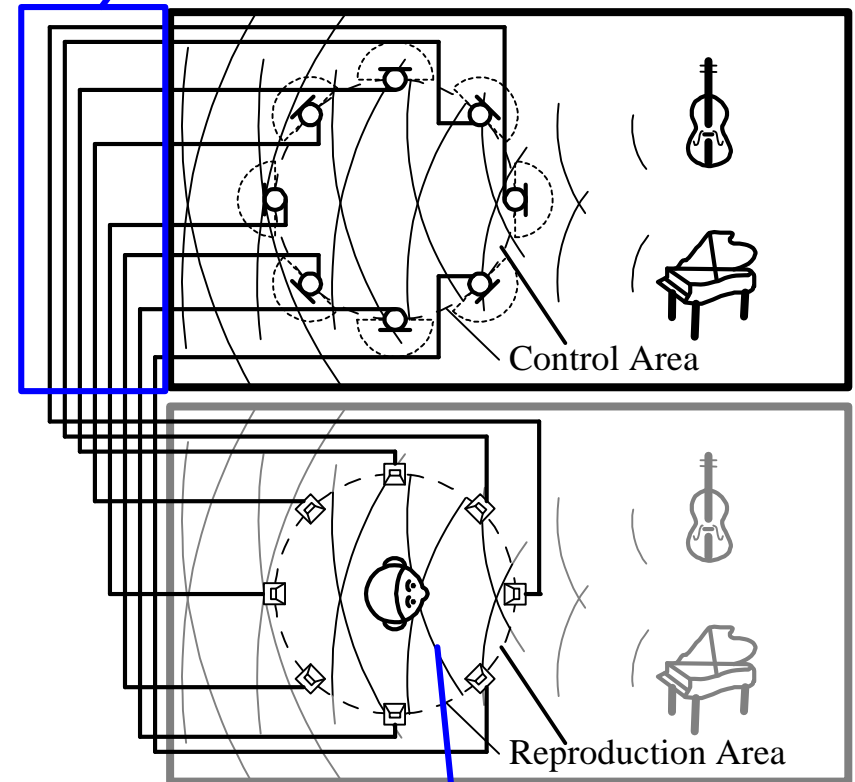
- Our target
 - The realization of sound field reproduction system based on wavefield synthesis:
- Aim of this report
 - The evaluation of the number of required channel signals due to the subjective assessment

1. Introduction

Sound Field Reproduction Technique

- Wavefield synthesis
 - It needs a great number of channel signals
- In the realization of reproduction system,
 - It is very important to evaluate the number of required channel signals

Channel signals



Synthesized wavefronts

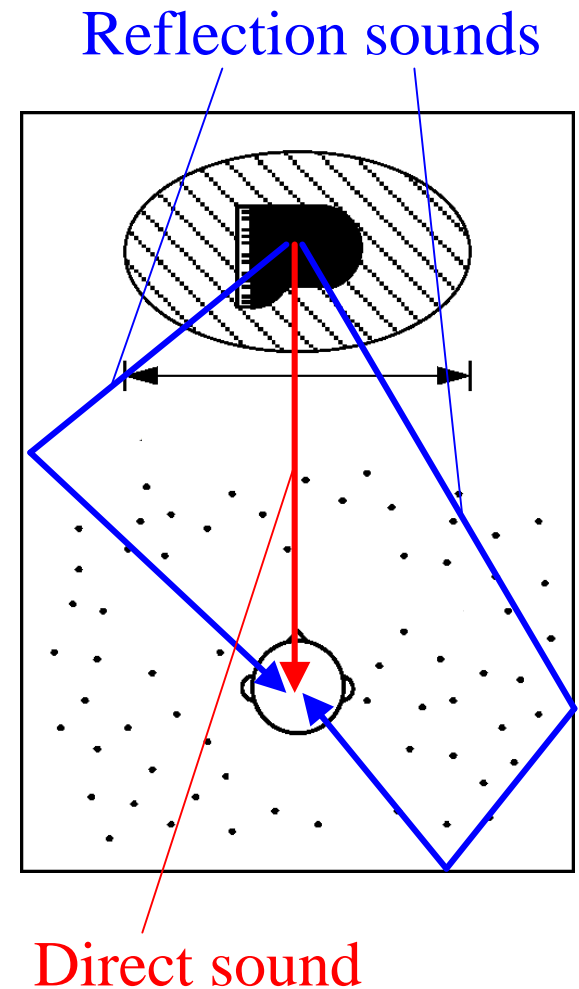
Evaluation of the Number of Required Channel Signals

- Objective approach
 - The accuracy of reproduced field by physical wavefronts
 - There are many studies
- Subjective approach
 - The subjective quality of the sound field
 - There are few studies

Evaluation of the number of required channel signals based on the subjective assessment

Dimensions of Sound Field Perception

- Directional perception
 - Physical factor
 - Direct sound only
- Distant perception
 - Physical factor
 - Direct and reflection sounds
- Spatial impression
 - Physical factor
 - Reflection sounds only



2. Subjective Assessment

Experimental Room

Scale

Acoustical transparent curtain
(No visual information for the loudspeakers)

Headrest
(Head is fixed
to the front)



Experimental Setup

Number of loudspeakers	23
Sound Field	Free space
Dry source	White noise & Speech
Number of source	1
Duration of source	1sec
Noise level	25.0dB(A)
Sound pressure level	About 60dB(A)

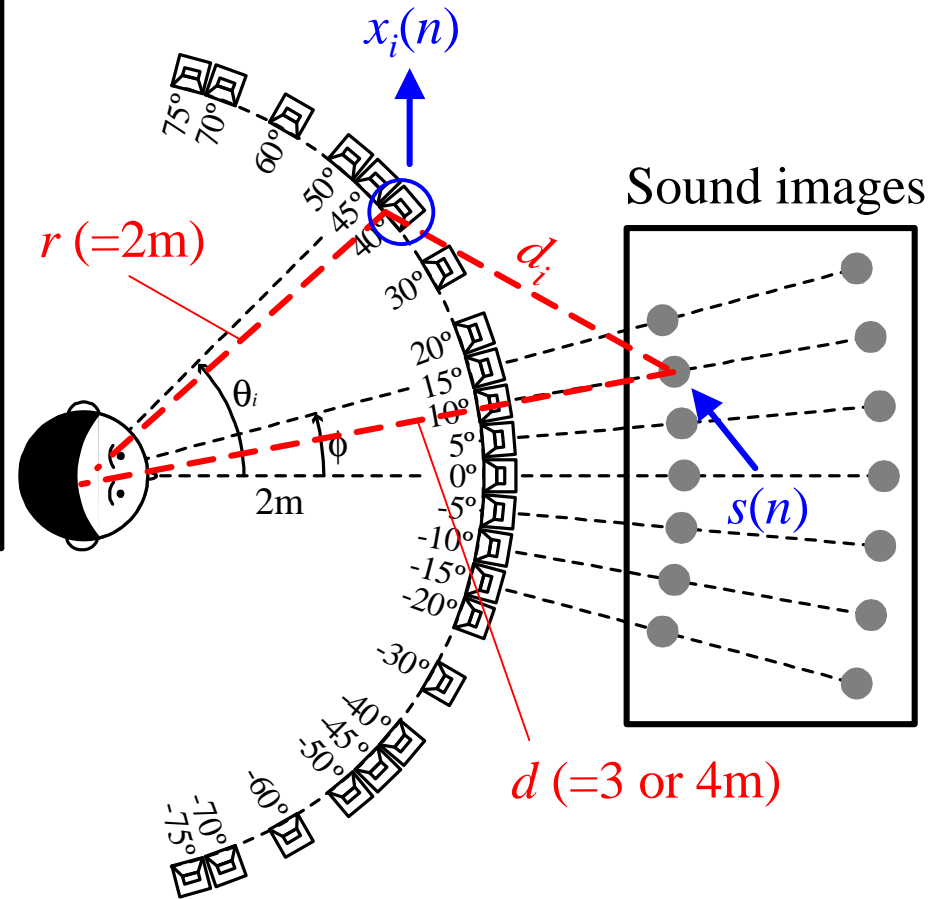
Calculation of channel signals

$$x_i(n) = \frac{d-r}{d_i} s(n - \text{round}\left(\frac{d_i F_s}{c}\right))$$

$$d_i = \sqrt{d^2 + r^2 - 2dr \cos(\phi - \theta)}$$

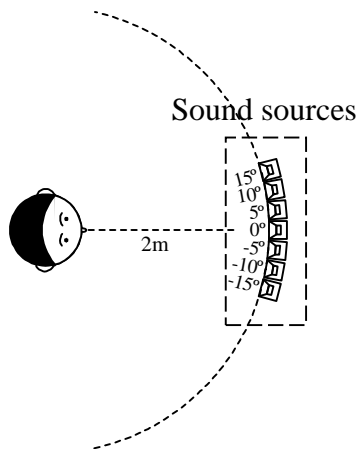
F_s (=48kHz): Sampling frequency

c (=340m/s): Sound velocity

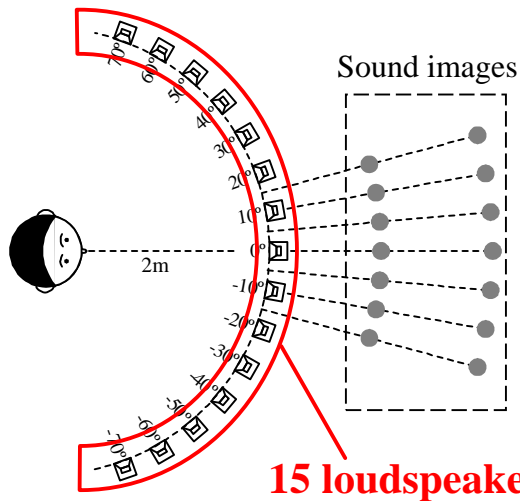


Experimental Conditions

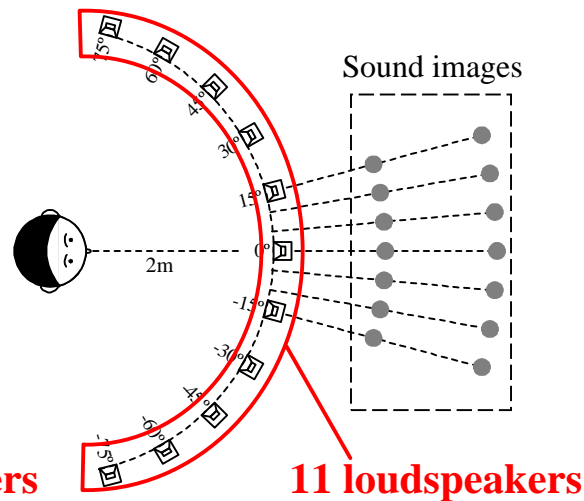
(a) Control Condition



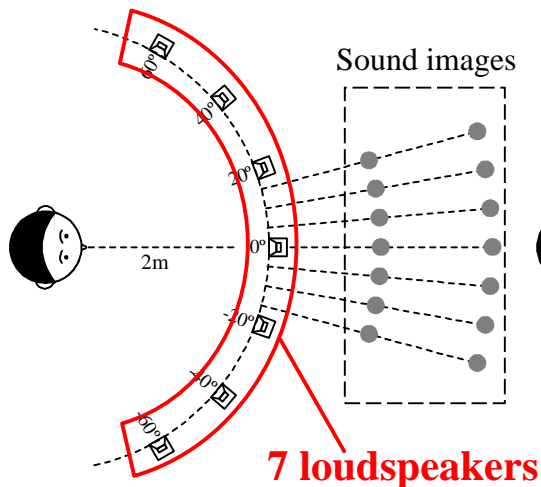
(b) 10° Azimuth Interval



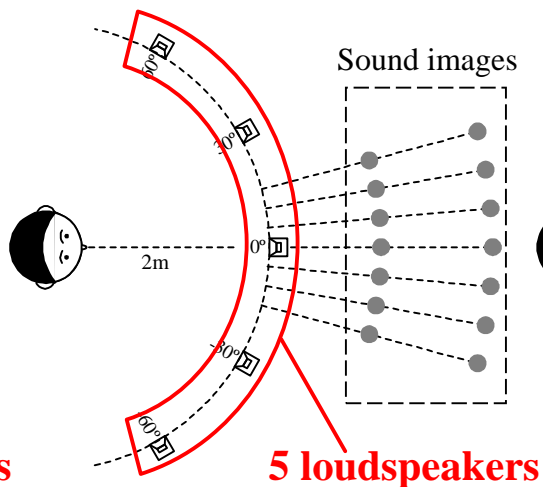
(c) 15° Azimuth Interval



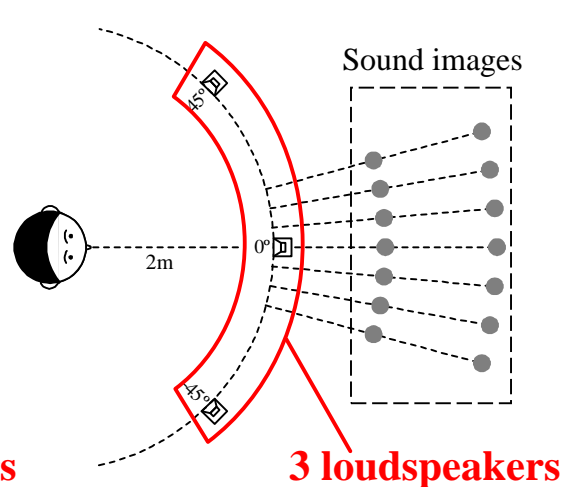
(d) 20° Azimuth Interval



(e) 30° Azimuth Interval



(f) 45° Azimuth Interval



Experimental Design

- **Subjects**

- Number...8
- 4 males & 4 females

- **Trials**

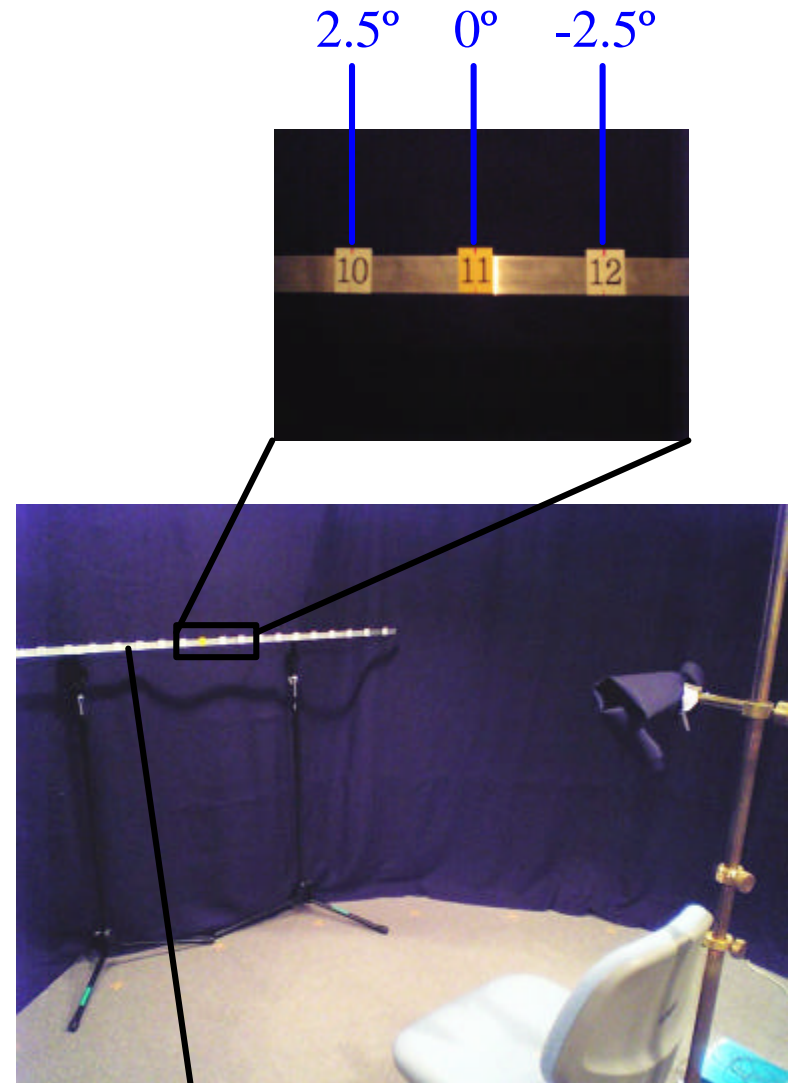
- Practice (14 trials)
 - = 1 (distance: 3m)
 - × 7 (directions: 0° , $\pm 5^\circ$, $\pm 10^\circ$ & $\pm 15^\circ$)
 - × 2 (control & 10° azimuth interval)
- Main (336 trials)
 - = 2 (distances: 3 & 4m)
 - × 7 (directions: 0° , $\pm 5^\circ$, $\pm 10^\circ$ & $\pm 15^\circ$)
 - × 6 (control, 10° , 15° , 20° , 30° & 45° azimuth intervals)
 - × 4 (repetitions)

Subjective Assessment

Session 1		Session 2			
Order...Randomized (White Noise or Speech)					
Session					
Practice (21 trials)	Main (308 trials)				
	(77)	(77)	(77)	(77)	(77)
Trial (Procedure)					
Stimulus (1 s)	Answer (4 s)				

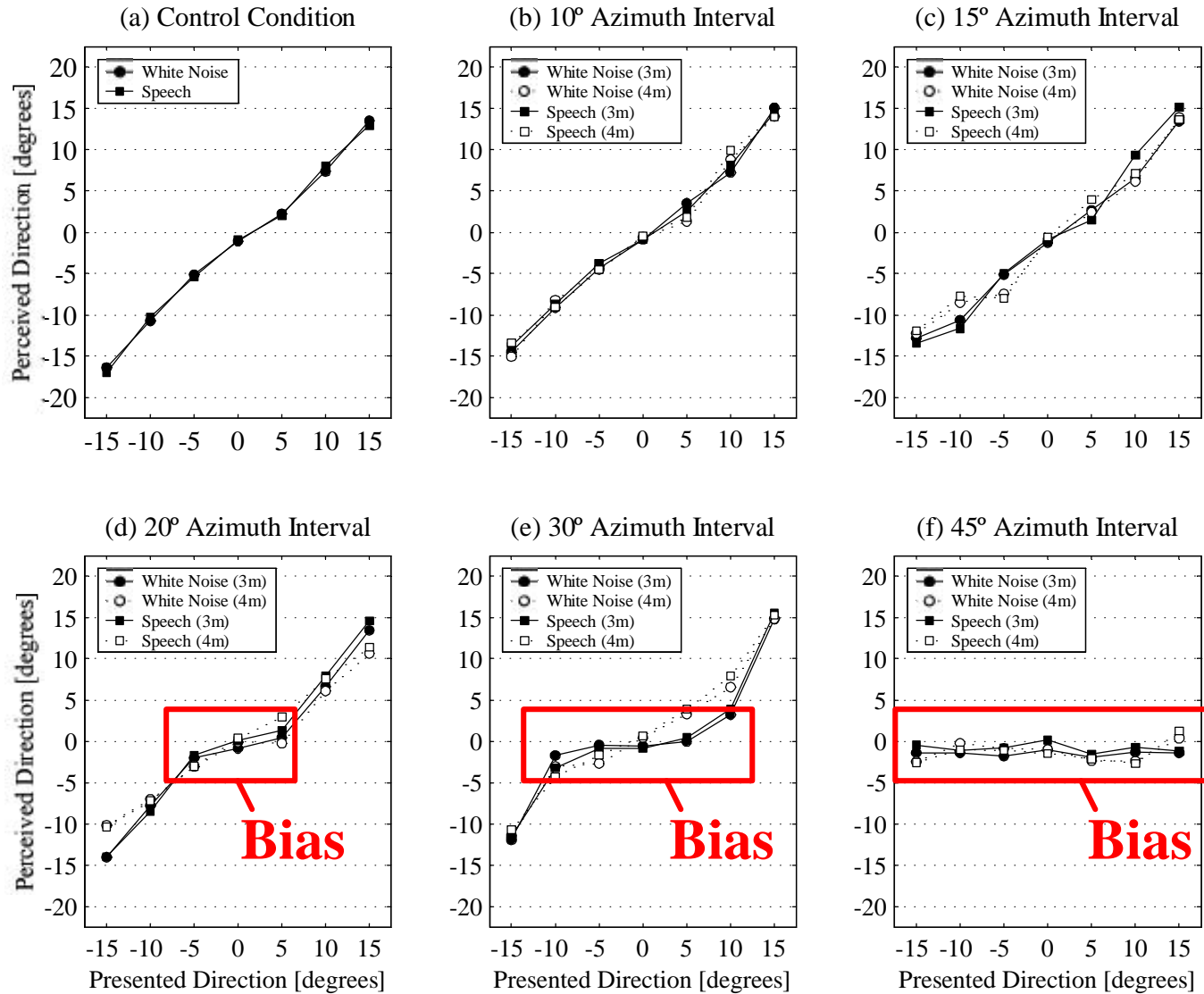
Experimental Procedure

- Instruction
 - Report the direction of sound
 - According to a number on a scale
- Scale
 - Marking at every 2.5° interval
 - Range: from -25° to 25°

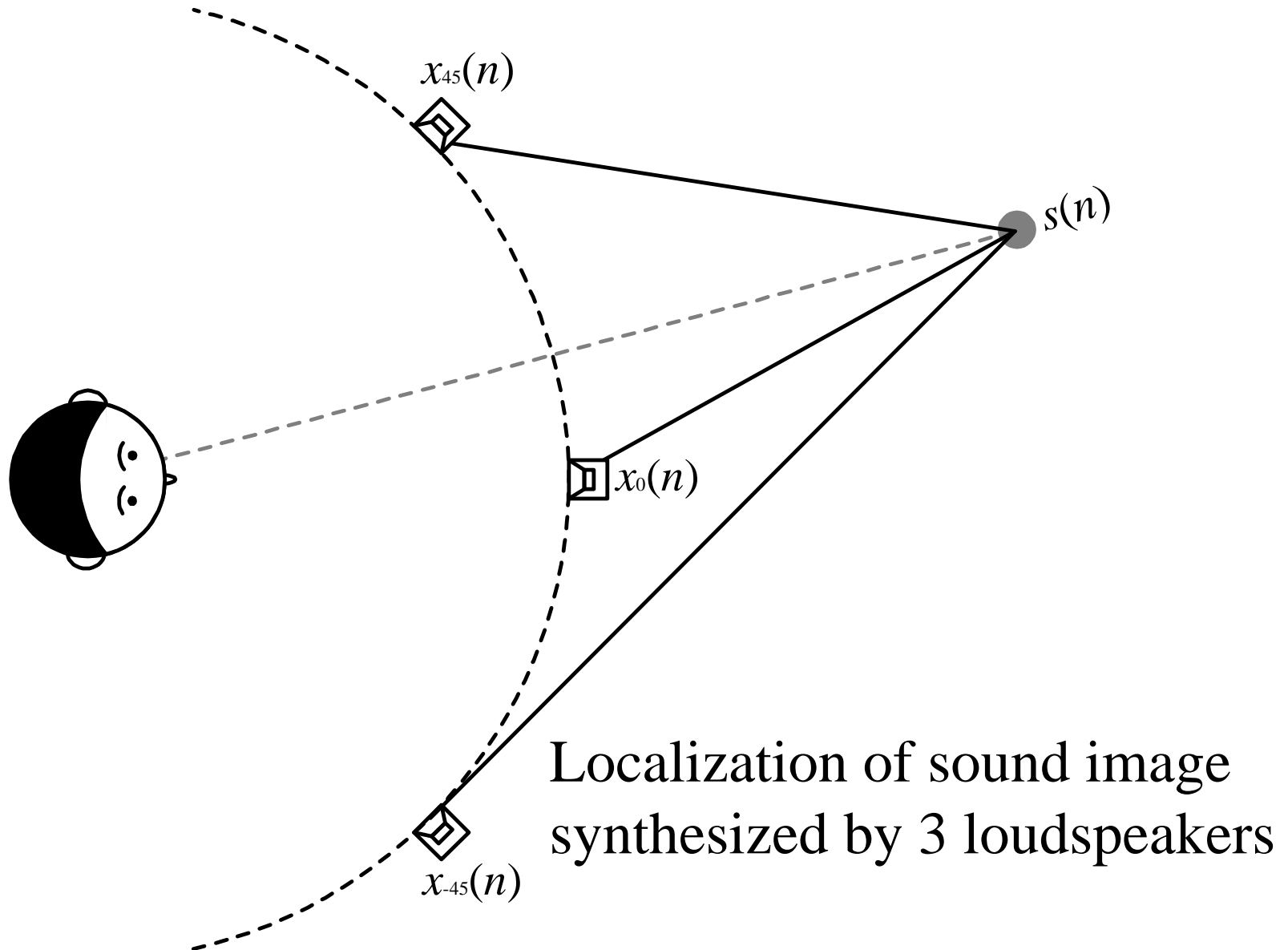


Scale for answer

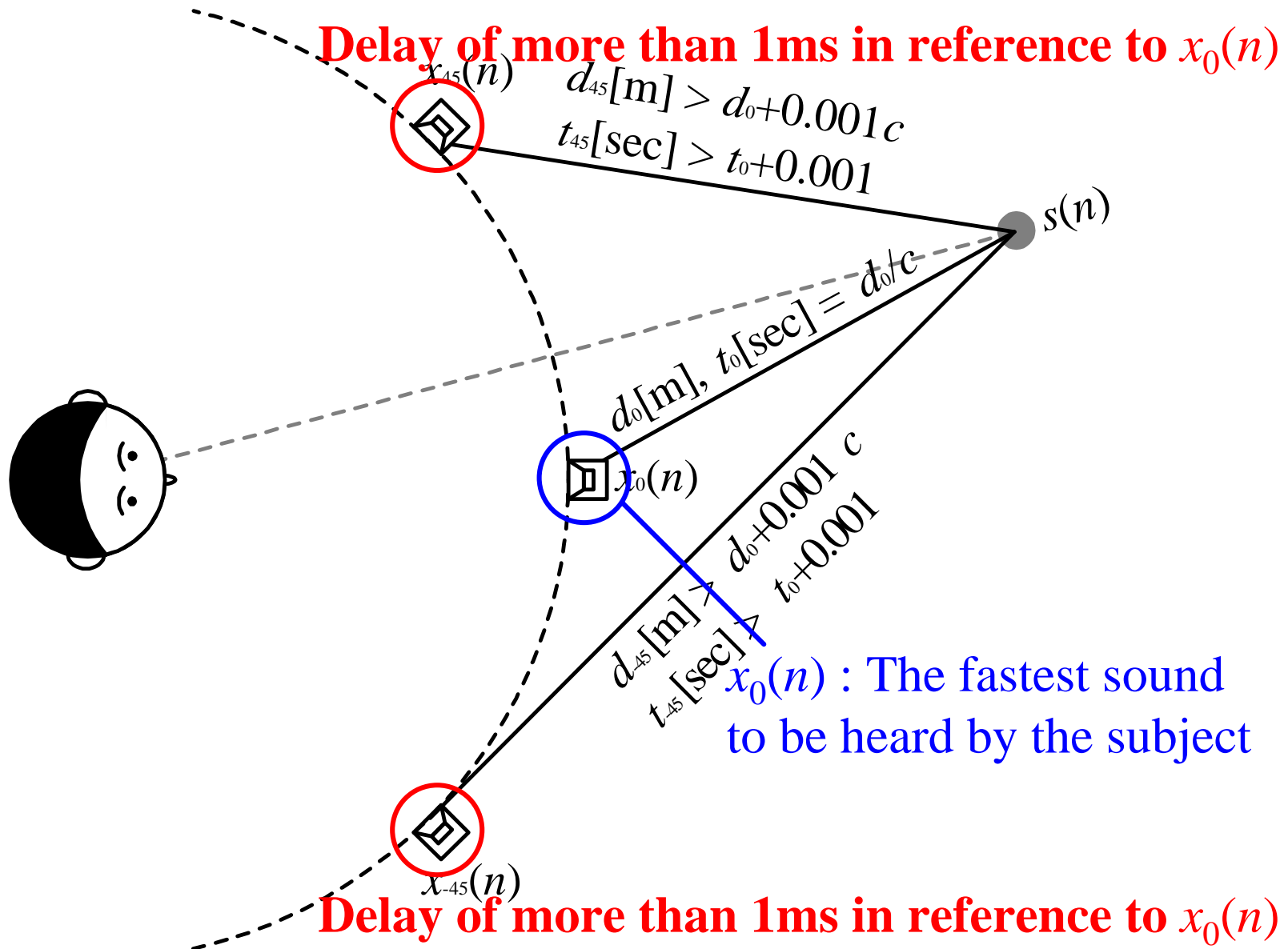
Results



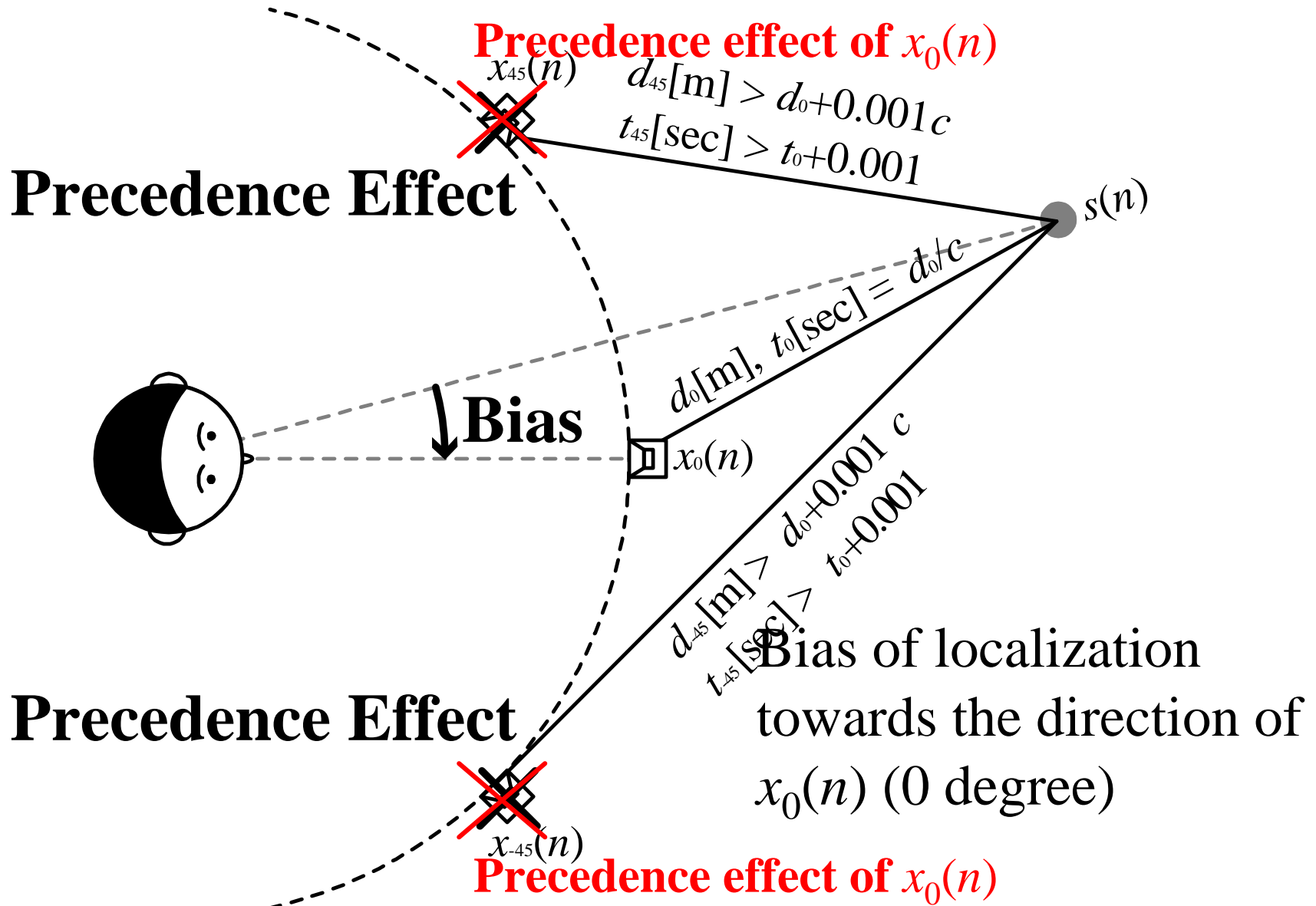
Cause of Bias



Cause of Bias



Cause of Bias



Discussion

- Less than 15° azimuth interval
 - Localization is almost the same as that in the control condition
- More than 20° azimuth interval
 - Bias of localization occurs by precedence effect

It needs to set the azimuth interval less than 15° in order to prevent the occurrence of precedence effect.

Discussion (cont')

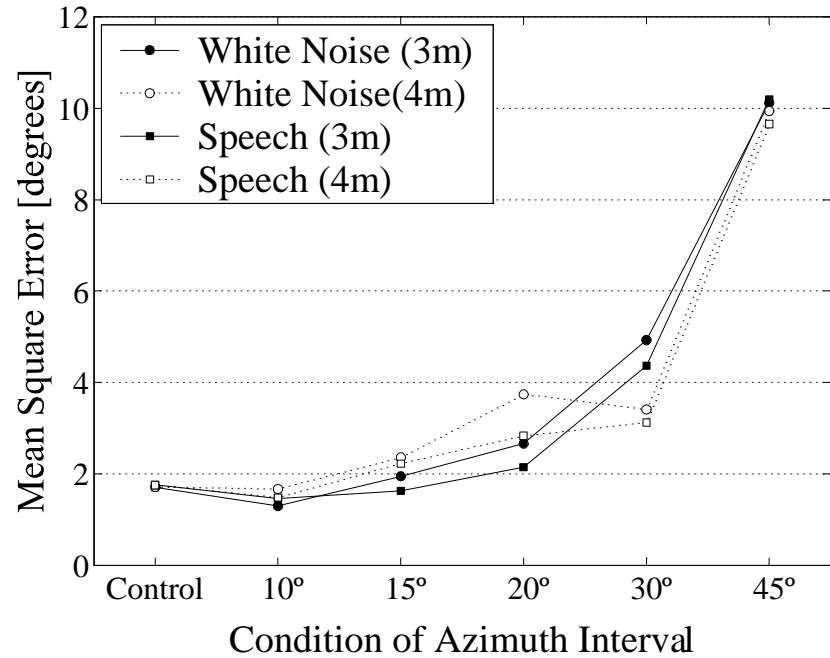
Mean Square Error

$$MSE = \sqrt{\frac{1}{N} \sum_{i=1}^N \{D_i - D'_i\}^2}$$

D : Presented direction [degrees]

D' : Perceived direction [degrees]

$N = 7$ ($0^\circ, \pm 5^\circ, \pm 10^\circ, \pm 15^\circ$)



- Less than 15° azimuth interval

– MSE...same as the control condition (about 2°)

→ **Number of required channel signals
...24 (radius 2m circle)**

Conclusion

- Evaluation of the number of required channel signals for the directional perception
 - Number...24 (on a circle of 2m radius)
 - MSE of localization...About 2°
- Future works
 - Evaluation of the number of required channel signals for the spatial impression
 - Development of the localization model that is able to predict the results of this subjective assessment