

Performance Evaluation of 3D Sound Field Reproduction System with a Few Loudspeakers and Wave Field Synthesis

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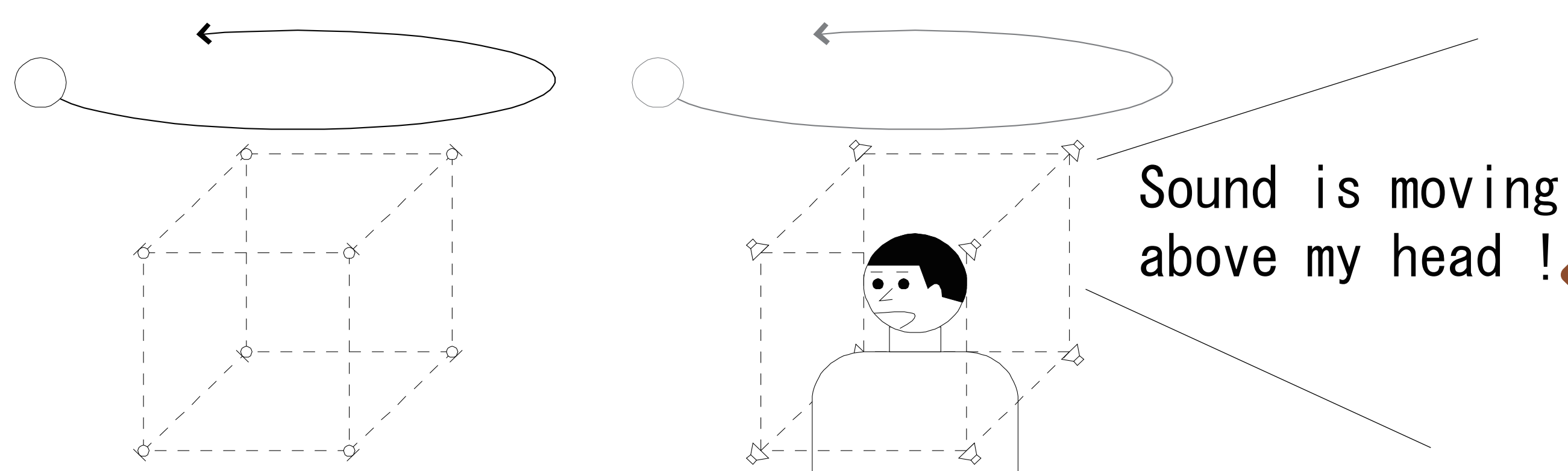
1. Purpose

Conventional 3D sound field reproduction system
 •Use of a great number of loudspeakers
 •Loudspeakers are visible in listener's field of vision

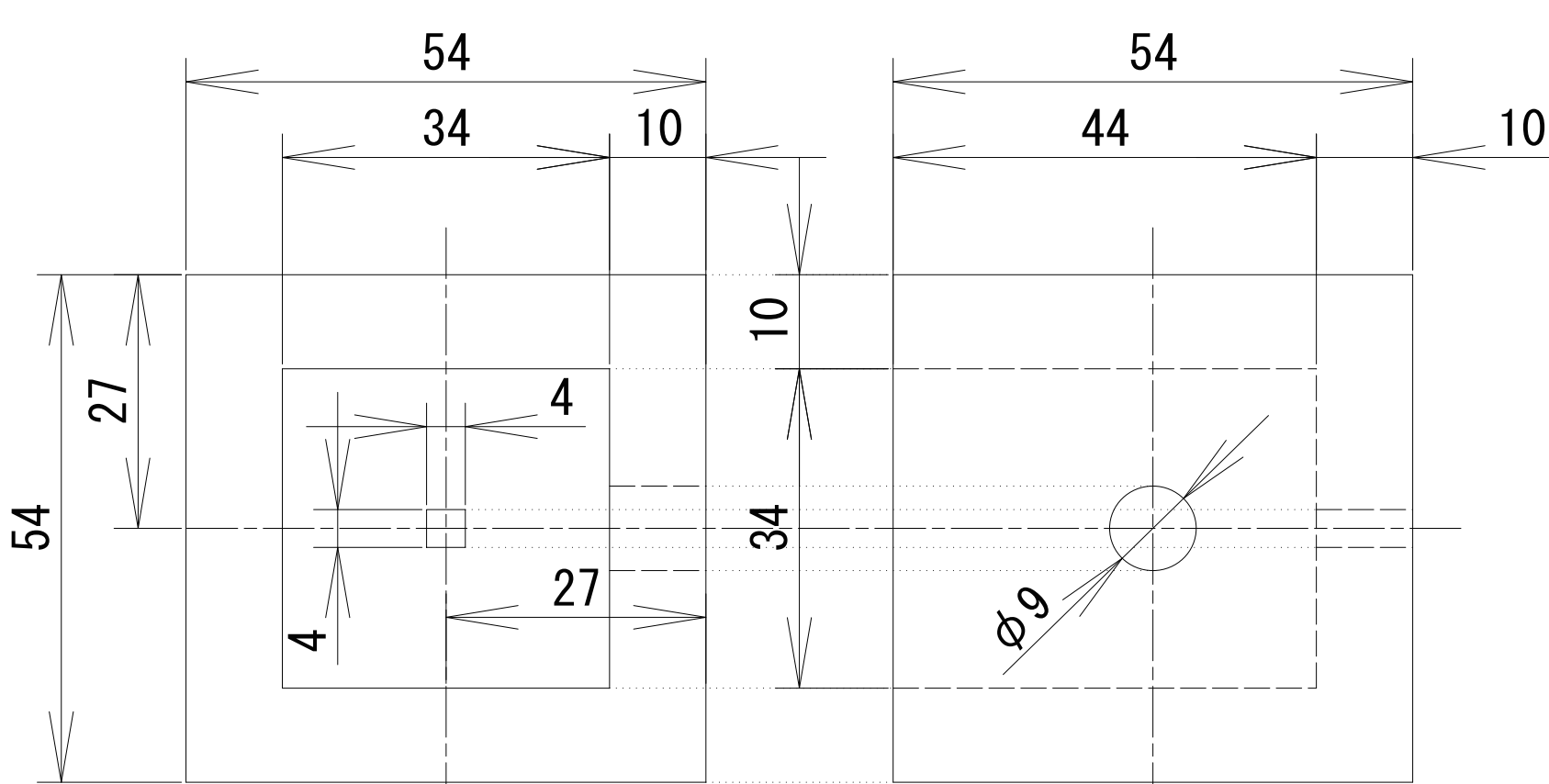
3D sound field reproduction system using a few loudspeakers is proposed

Diagram of proposed system

- ① Recording by eight directional microphones
- ② Playing the recorded sounds by eight loudspeakers
- ③ 3D sound field is reproduced in loudspeaker array



2. Manufacture of loudspeaker units



Design of loudspeaker box

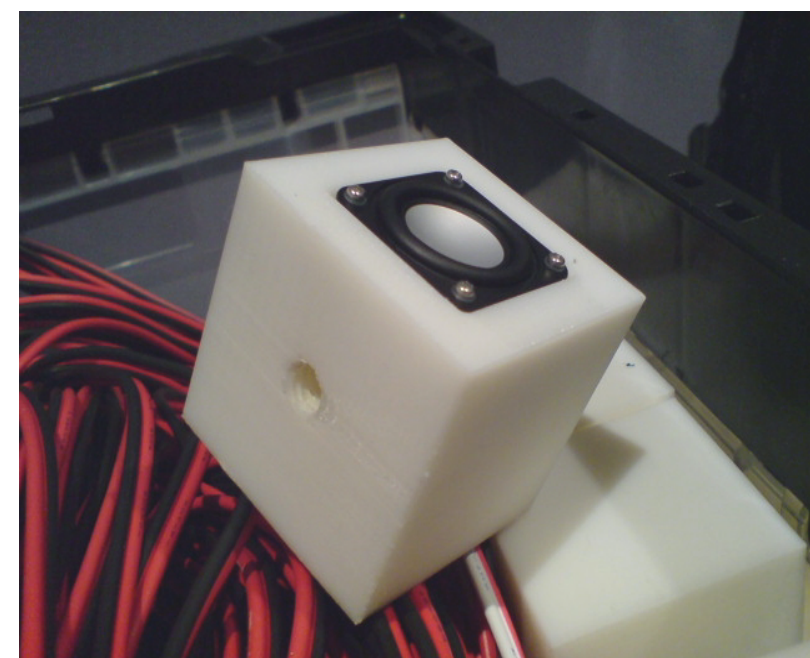
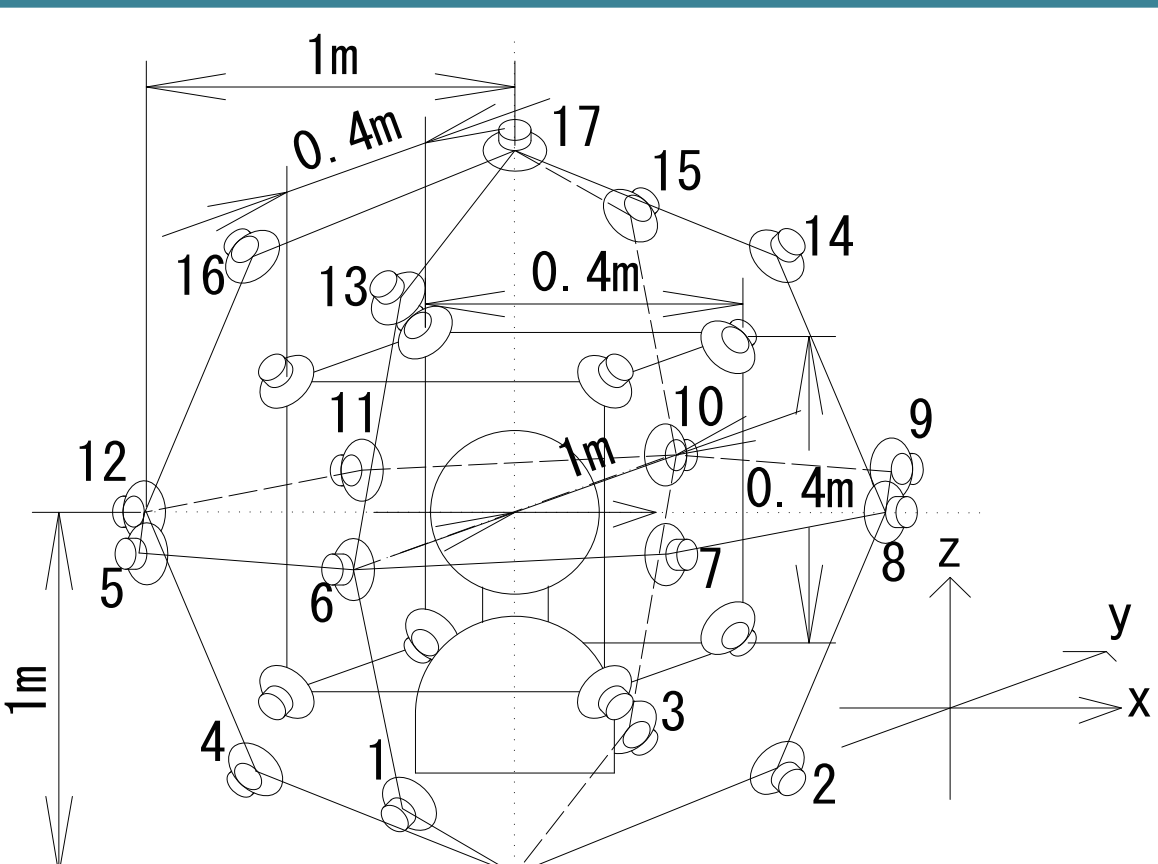


Image of the manufactured loudspeaker

This unit is used loudspeaker system.

3. Construction of experimental system



Position of a listener and the loudspeakers

Setup of the loudspeaker array and loudspeakers for the control condition

- Set eight loudspeakers
- Set seventeen loudspeakers for the control condition

4. Environment and procedure

The multi-channel signals played by the loudspeaker array were synthesized on a computer.

Room with a reverberation time : 180 ms
 Background noise level : 23 dB(A)
 Sound pressure level : 60 dB(A) at listening position
 Number of listeners : 6 males and 1 female
 Microphone directivity : Shotgun
 Sound source : White noise and speech
 How to answer : Answer perceived direction to the answer sheet

Practice : 2 conditions
 (control and distance 1 m)
 × 17 (directions) = 34

Main : 3 conditions
 (control and distance 1 m ,
 3 m) × 17 (directions)
 × 3 (repetitions) = 153

Azimuth and elevation angles of sound sources

Index	θ [°]	ϕ [°]	Index	θ [°]	ϕ [°]
1	-90	-45	10	90	0
2	0	-45	11	135	0
3	90	-45	12	180	0
4	180	-45	13	-90	45
5	-135	0	14	0	45
6	-90	0	15	90	45
7	-45	0	16	180	45
8	0	0	17	---	90
9	45	0			

Subjective Assessment

Session 1		Session 2	
Order...Randomized (White Noise or Speech)			
Session			
Practice (34 trials)	Main (153 trials)		
	(51)	(51)	(51)
Trial (Procedure)			
Stimulus (4 s)		Answer (5 s)	

Flow chart of the localization test

5. Result

$$\text{Accuracy rate} = \frac{\text{Number of True answers}}{\text{Number of presentations}} [\%]$$

Global accuracy rate ... Approximately 75%
 5 directions ... Accuracy rate is low

Results of a white noise source

Direction number	Control condition	1 m distance	3 m distance
1	100	81	76
2	95	100	95
3	100	81	86
4	95	76	90
5	100	100	100
6	100	43	52
7	100	100	100
8	100	33	43
9	100	100	100
10	100	52	43
11	100	100	95
12	100	48	33
13	100	90	90
14	95	100	100
15	100	76	86
16	86	71	71
17	100	38	33
Average	98	76	76

Unit:[%]

Results of a speech

Direction number	Control condition	1 m distance	3 m distance
1	100	86	81
2	86	76	86
3	100	100	100
4	90	81	71
5	95	95	95
6	100	43	57
7	100	100	90
8	100	67	62
9	100	76	90
10	100	57	52
11	100	90	90
12	95	76	33
13	100	76	81
14	100	95	95
15	95	71	71
16	86	67	52
17	90	48	52
Average	96	77	74

Unit:[%]

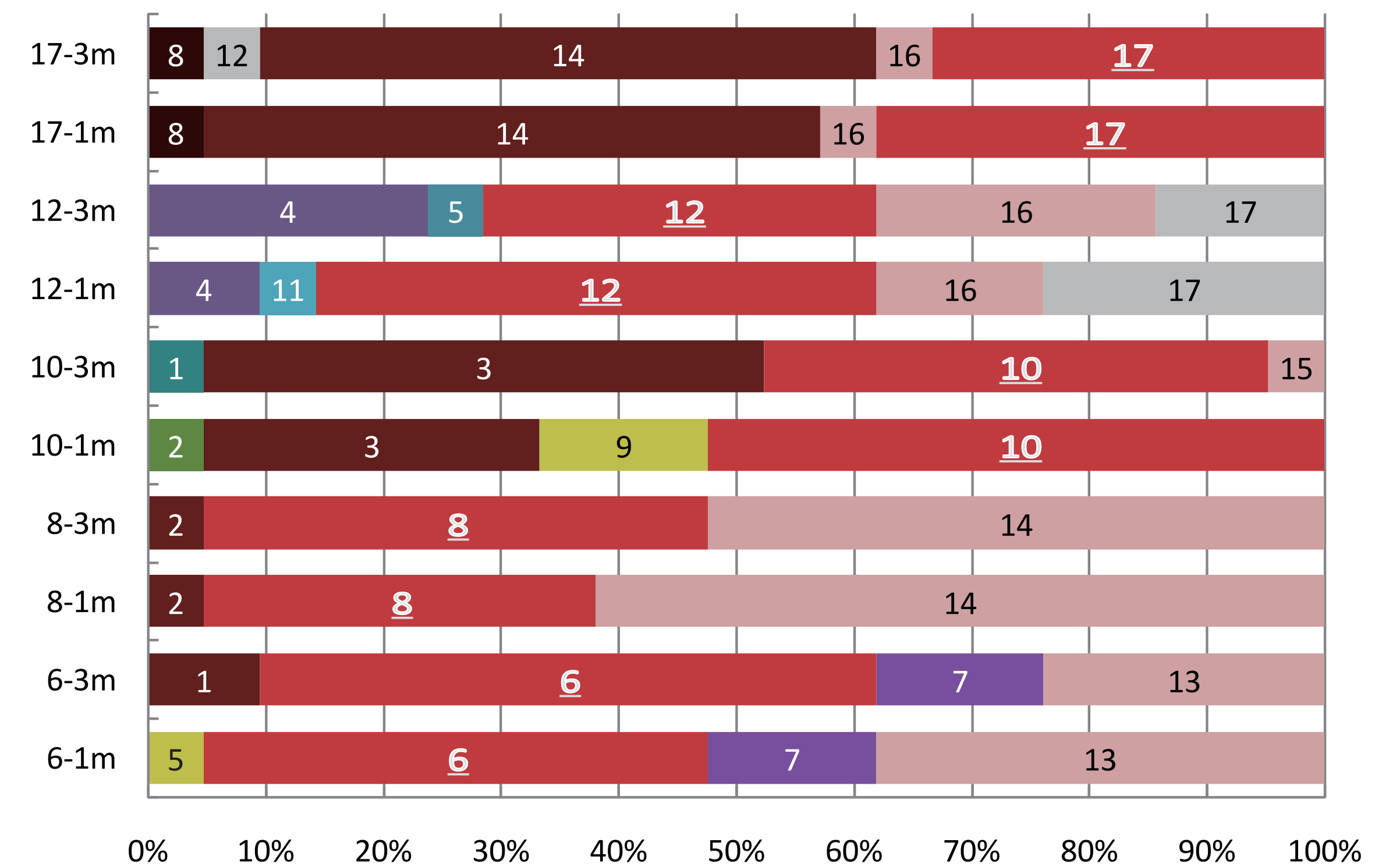
$$\text{Answer rate in 5 directions} = \frac{\text{Number of answers}}{\text{Number of presentations}} [\%]$$

5 directions (6, 8, 10, 12, 17)

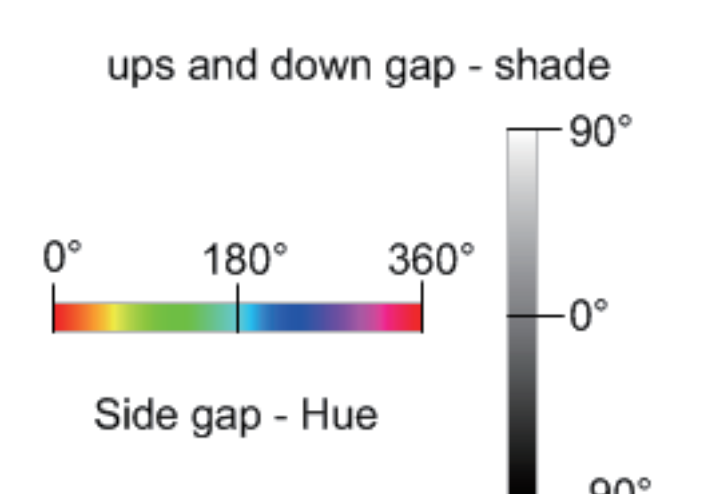
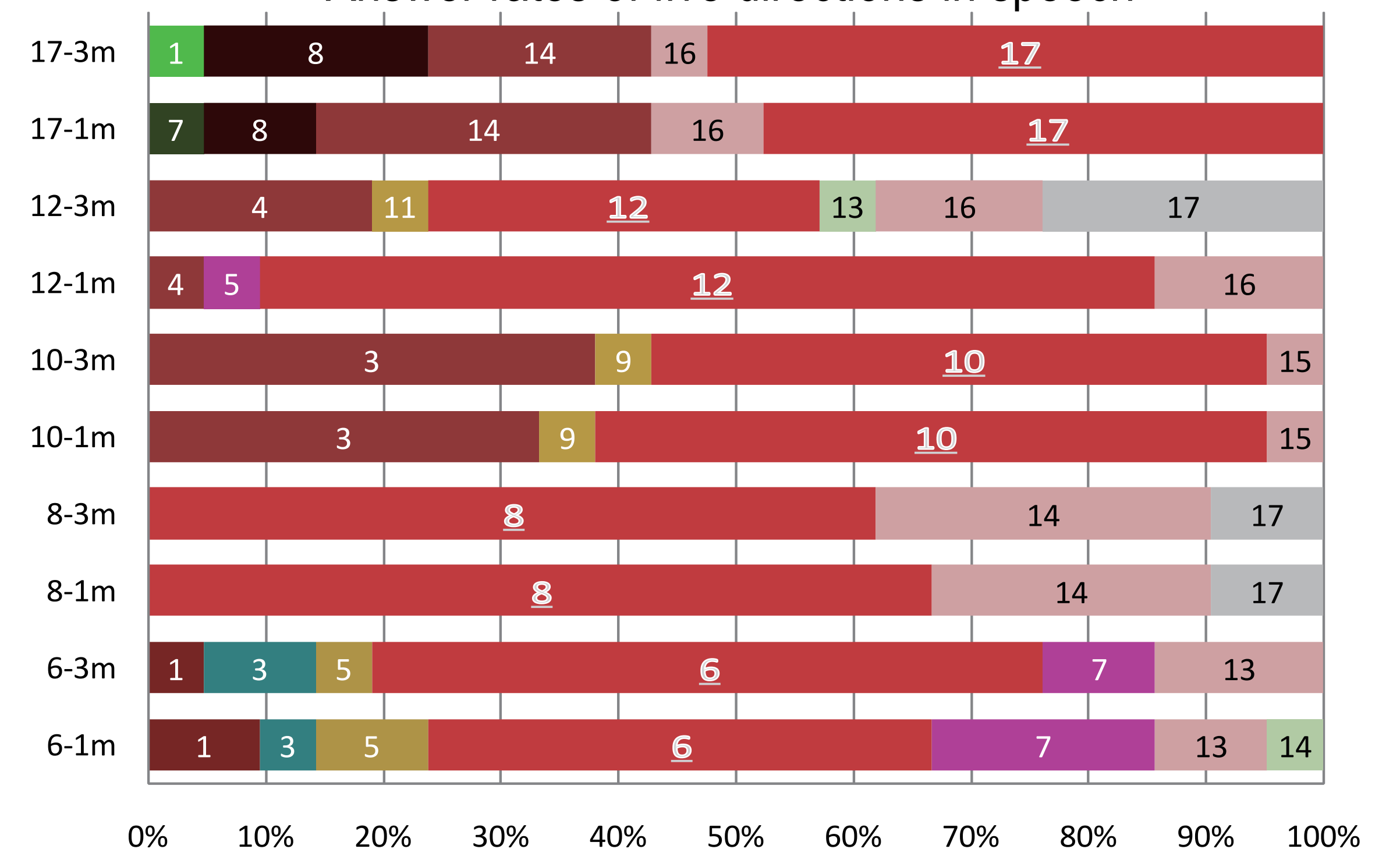
→ Identical signals are played from 4 loudspeakers.

The blur and bias in sound images occurs due to phantom sources.

Answer rates of five directions in white noise



Answer rates of five directions in speech



6. Conclusion

- We have proposed the system with eight loudspeakers to reproduce 3D sound field
- Good performance was observed for twelve of the seventeen directions that were used in the test
- It need to plan to develop a method to improve the localized accuracy of the remaining five directions