防災・減災情報を効果的に伝送するメッシュネットワーク型インテリジェント拡声システムの研究開発

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Information flow on warning system

→ multiple paths to deliver disaster messages.

Topic : Disaster mitigation utilizing public address

In the Great East Japan Earthquake, among residents who could obtain evacuation announcements in the affected prefectures, 45% of them obtained it from outdoor loudspeakers.

However, among those who obtained evacuation announcements from outdoor loudspeakers, only 56% of them answered they could clearly hear the announcements.

Topic : Disaster mitigation utilizing public address

Problems : Residents in a house.

Difficulty on hearing in a field.

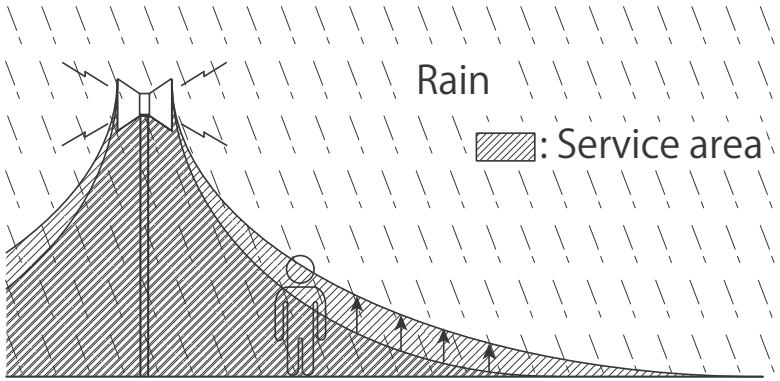
Reasons : Overlapping of sounds from other public address system or reflected sounds by building, mountain, woods, and so on.

Topic : Disaster mitigation utilizing public address

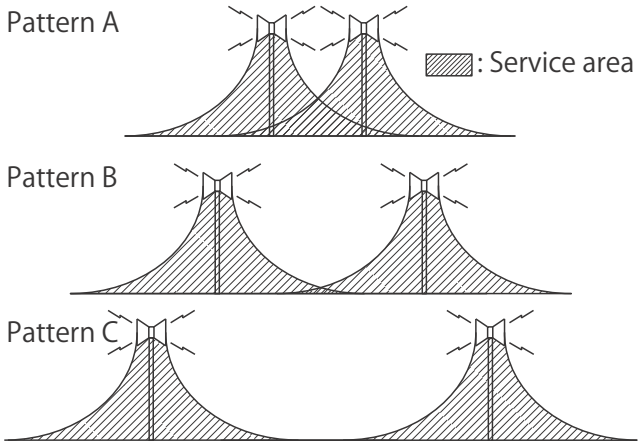
What functions are expected?

- Timing control
- Sound pressure level control
- Directivity control

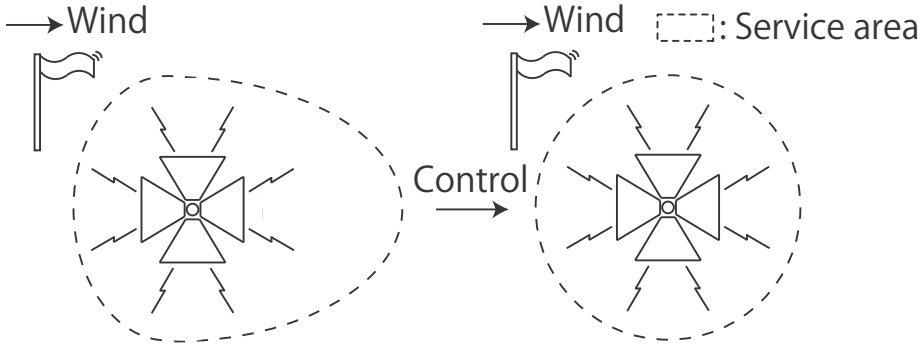
SNR



Sound overlapping

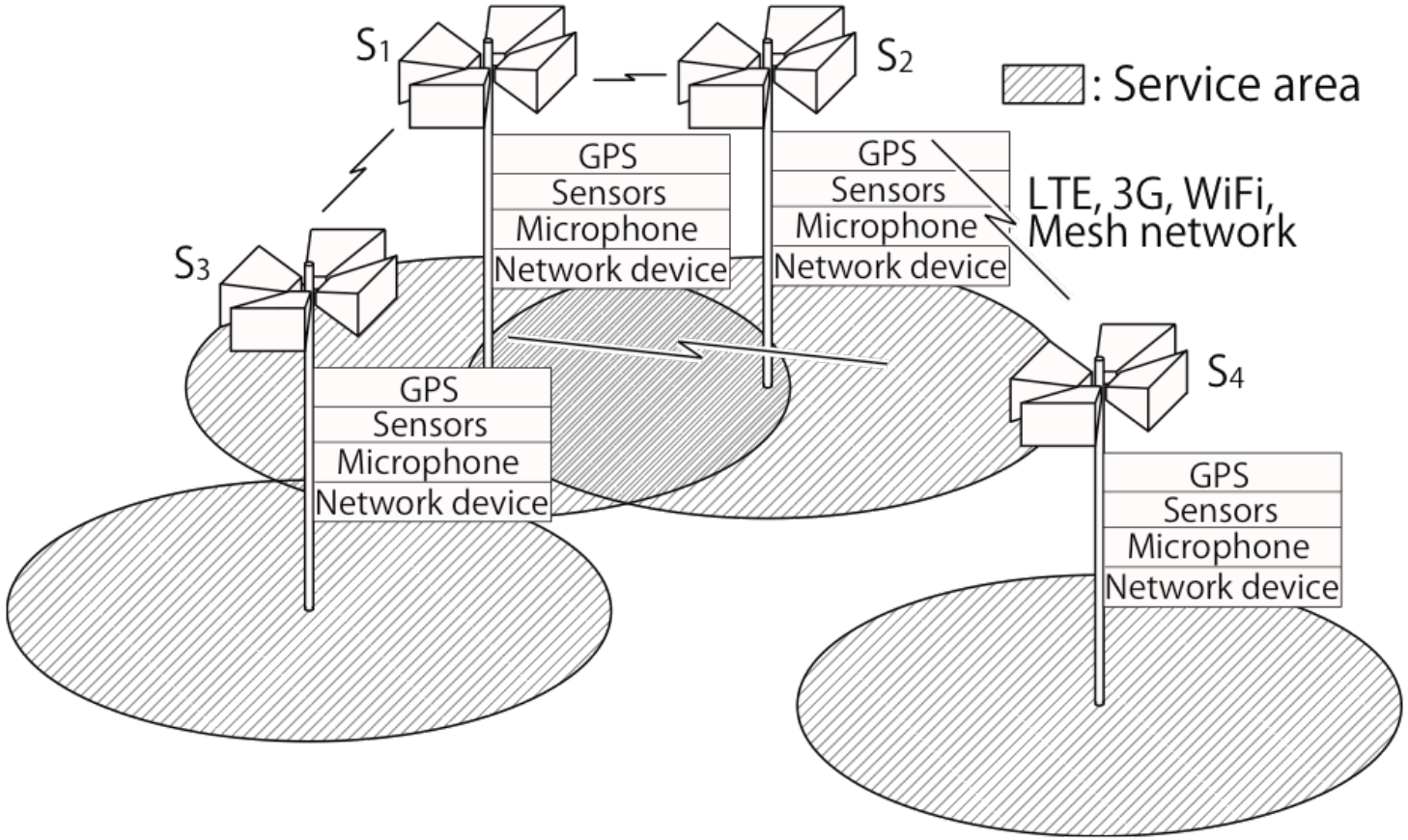


Wind / Temperature



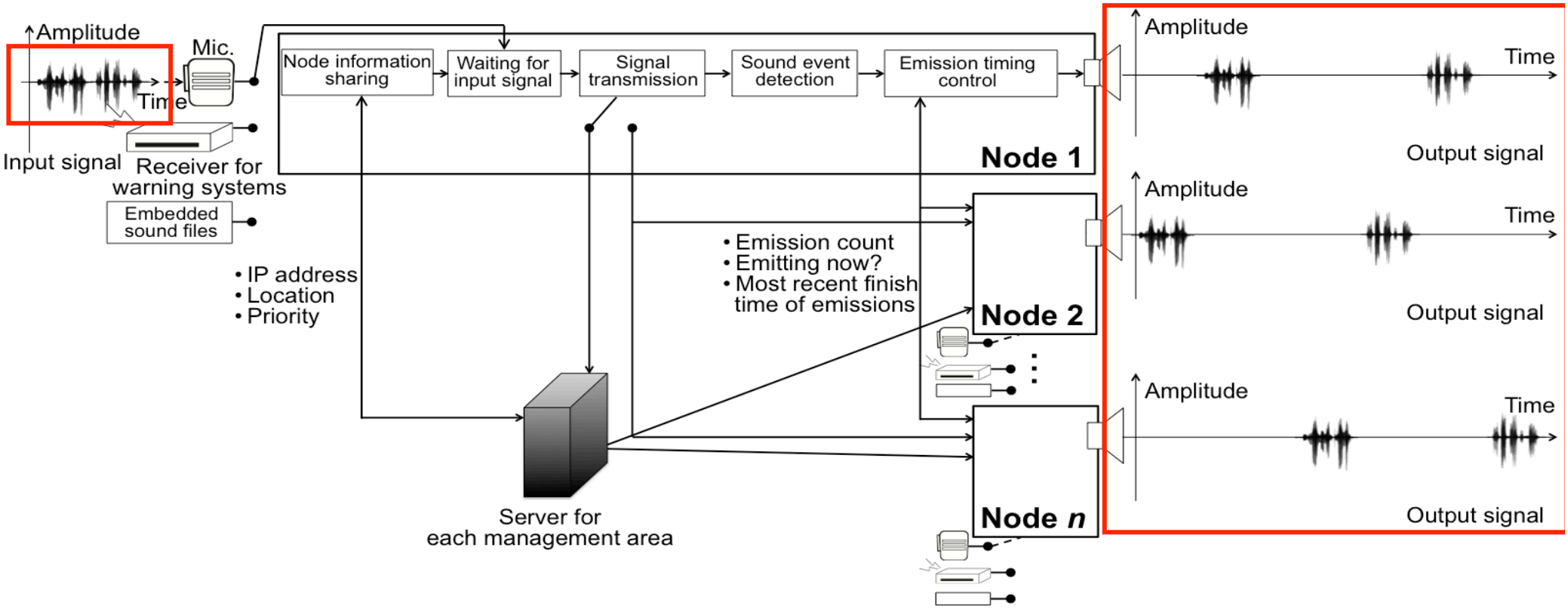
Topic : Disaster mitigation utilizing public address

- Timing control is implemented to improve signal to interference ration at overlapped area.



Emission timing controller

- Emission timing control



Emission timing controller

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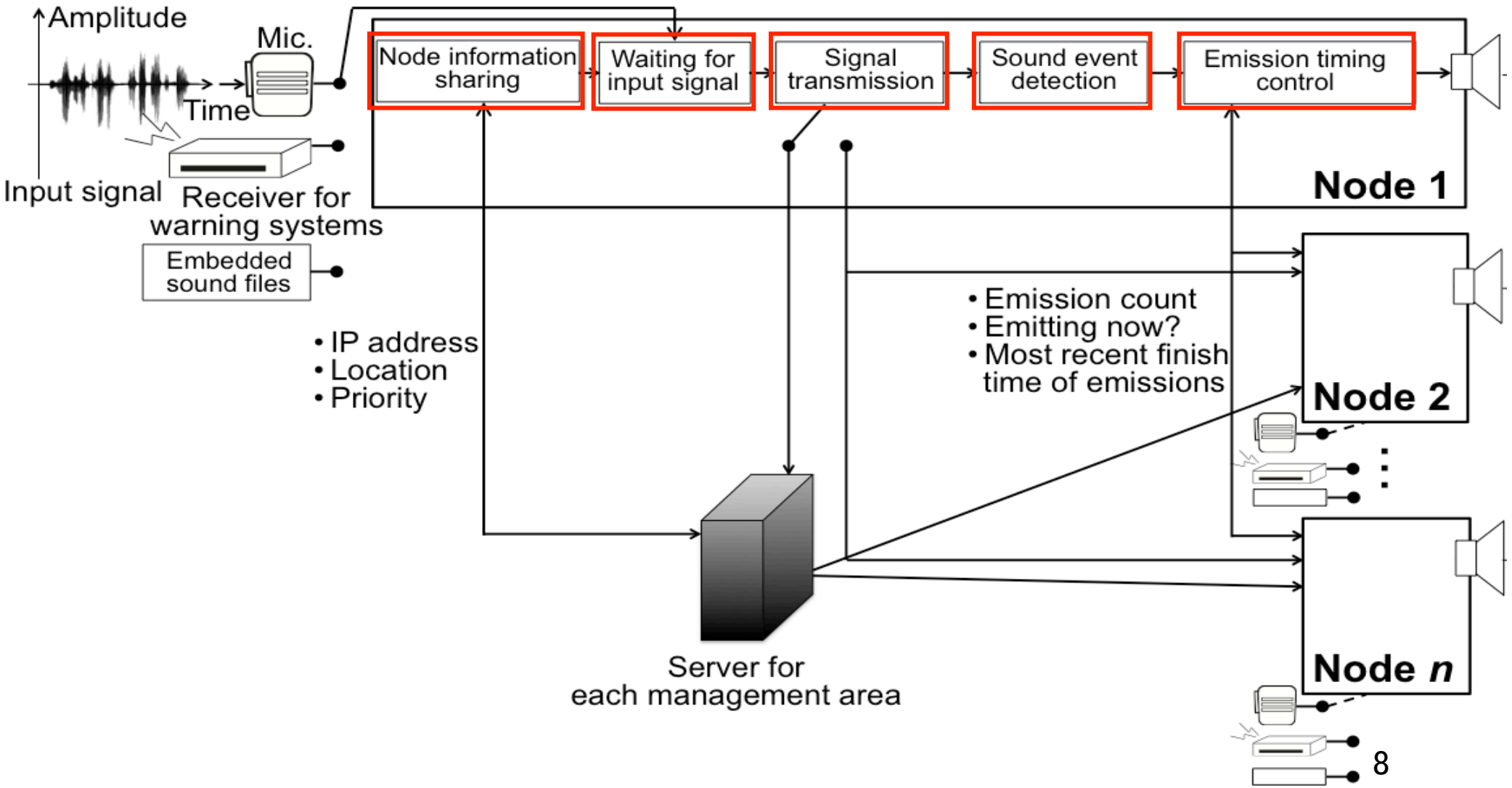
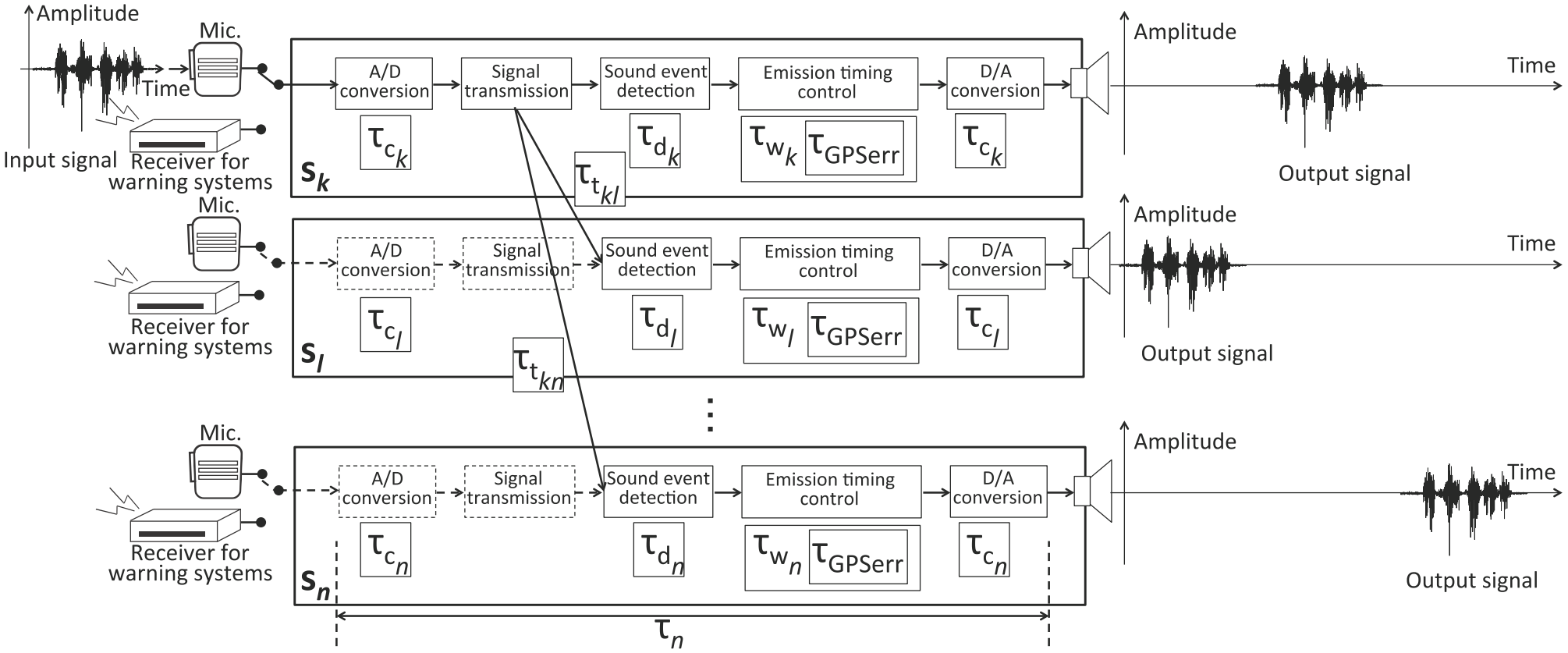


Processing time

- total delay from input to output

$$\tau_n = \tau_{ck} + \tau_{tkn} + \tau_{dn} + \tau_{wn} + \tau_{cn}$$



Block diagram

Errors on each block

total delay $\tau_n = \tau_{ck} + \tau_{tkn} + \tau_{dn} + \tau_{wn} + \tau_{cn}$

τ_{ck}, τ_{cn} : A/D, D/A conversion

τ_{tkn} : transmission time

1 frame data(bits) / throughput(bps)

depends on network.

e.g. PCM 16 bits, 1 frame = 1024 samples,

LTE 2 Mbps < 10 ms

τ_{dn} : sound event detection

e.g. 10 ms(ITU G7.29 AnnexB)

τ_{wn} : emission timing control

Intelligent public address system

The detailed system and its performance is described in

Emission timing control method for improving signal to interference ratio on public address system

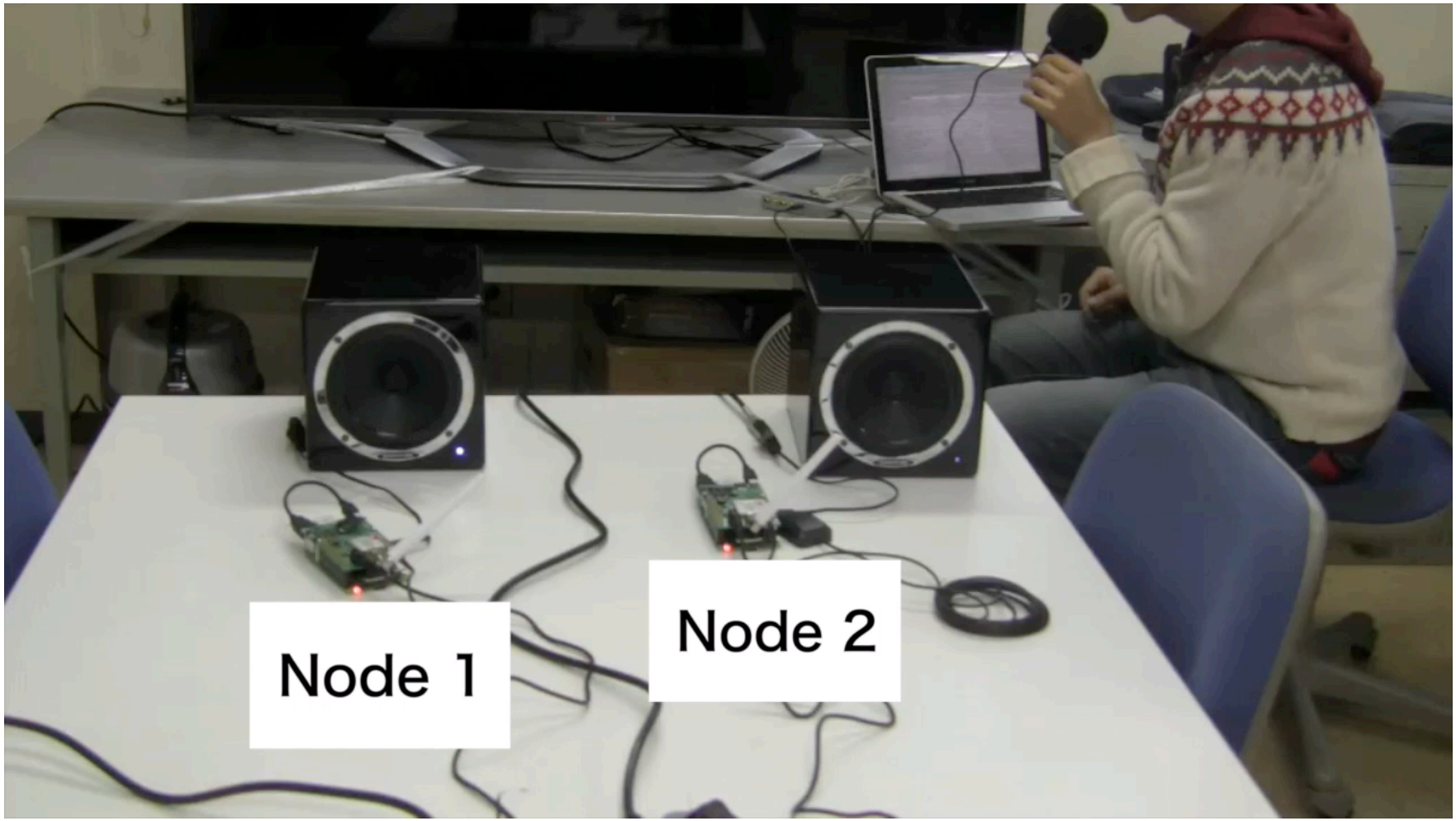
Taira Onoguchi, , Dan Murakami, Yoshifumi Chisaki

Applied Acoustics

Volume 98, November 2015, Pages 70–78

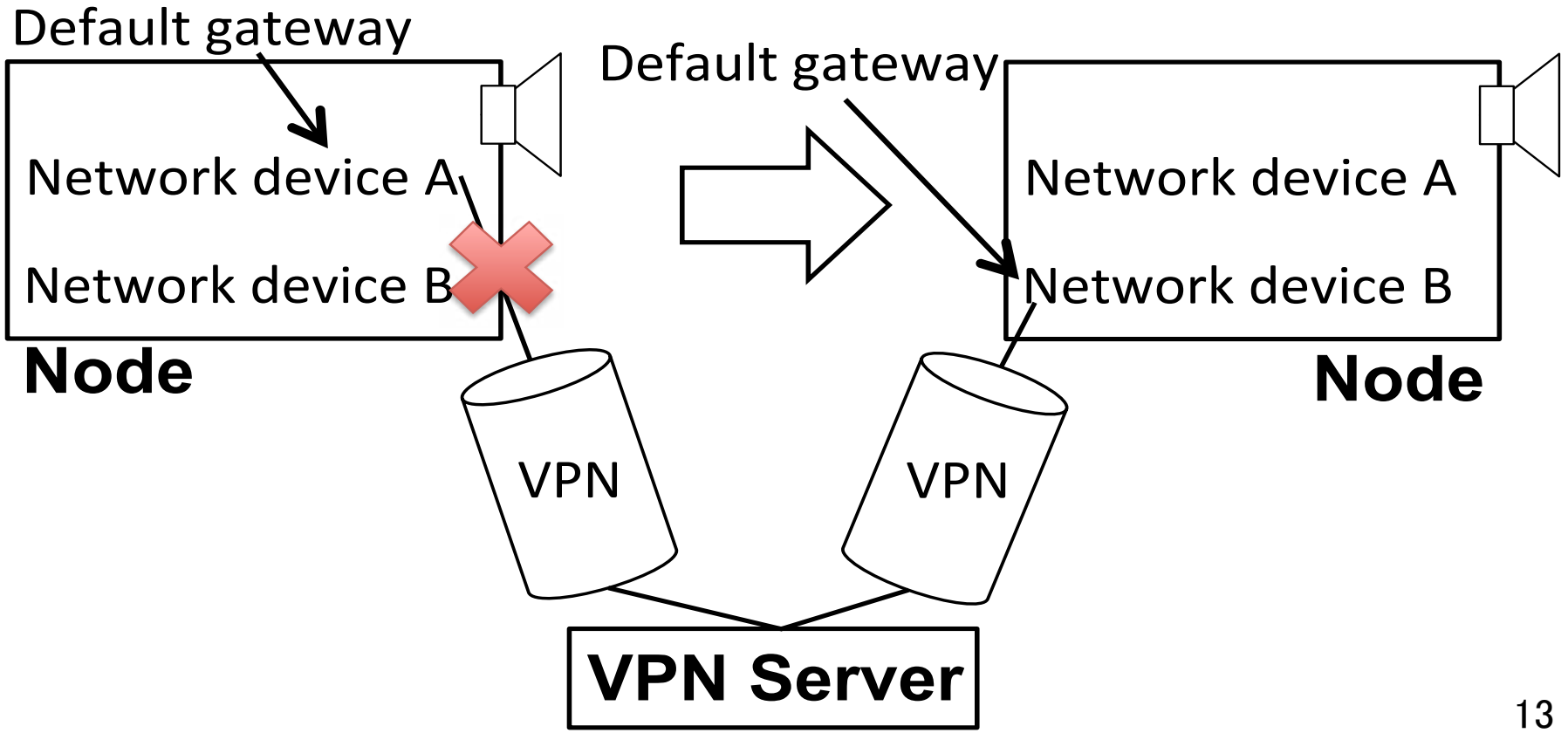
Demonstration

(Residents in Kurokami area, move to higher place in Japanese.)



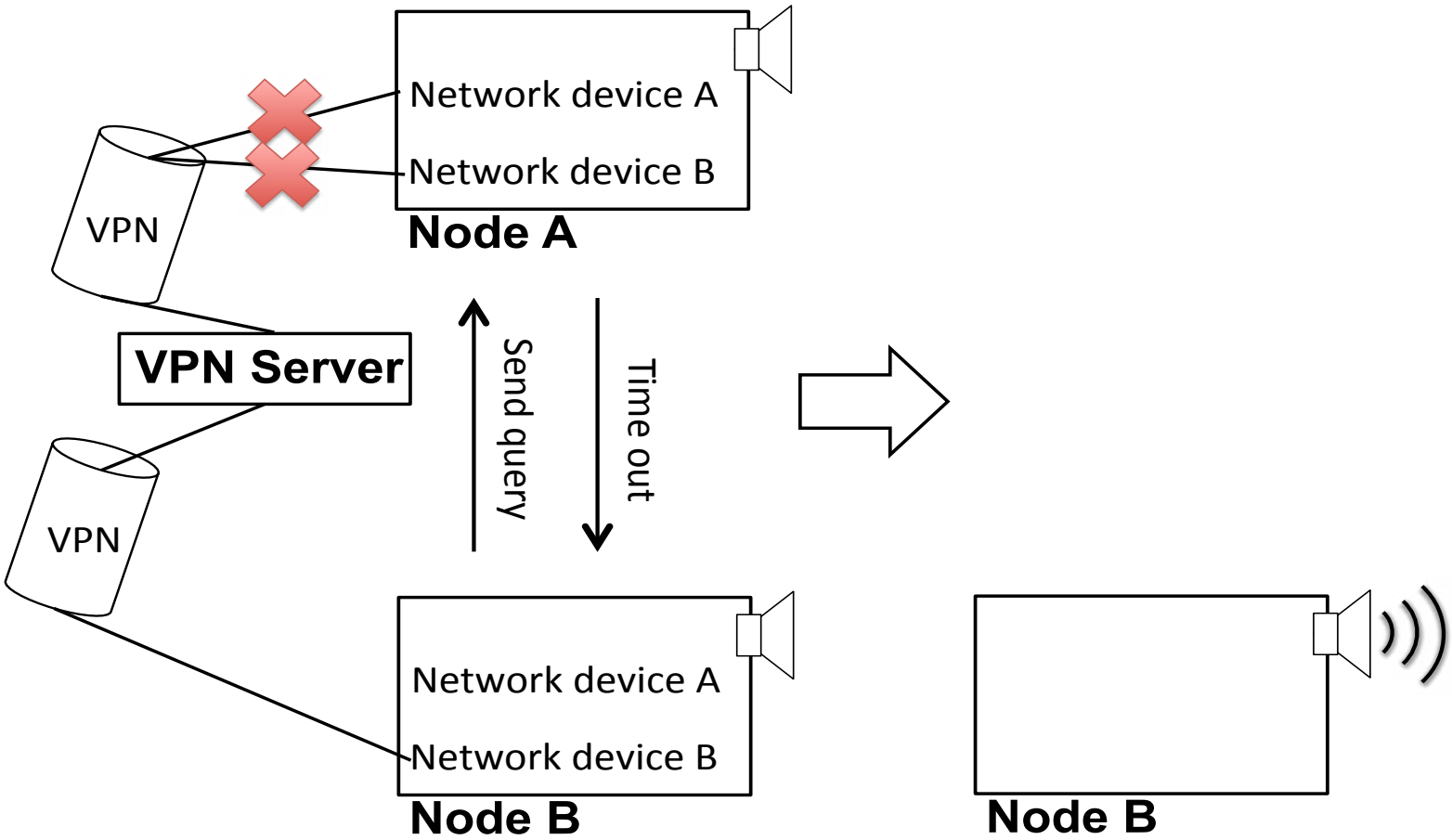
Functions to increase reliability

- Automatic network selector
  - Nodes and a server automatically change their default gateway to select the active and widest bandwidth network.



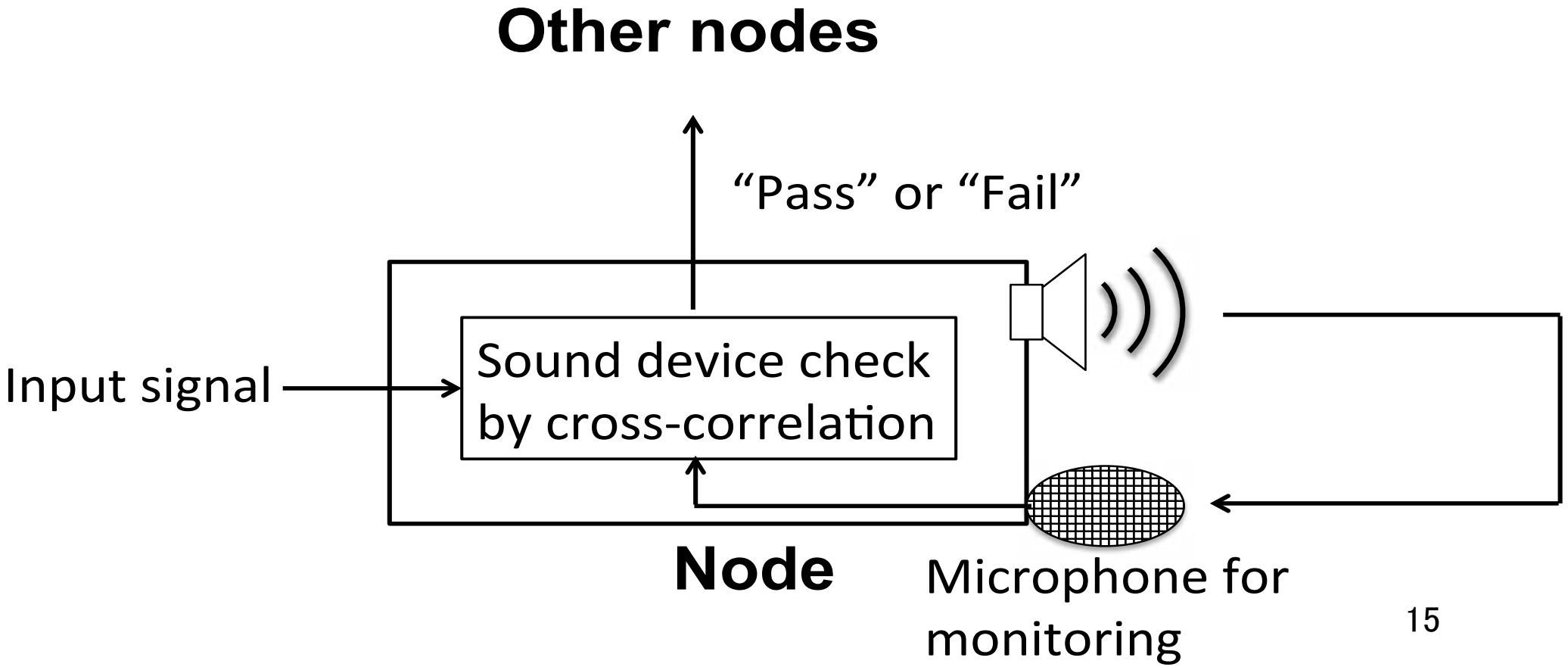
Functions to increase reliability

- Fail safe structure for network disorder
  - If all of network devices of a node are down,
    other nodes determine emission timing without considering that node.



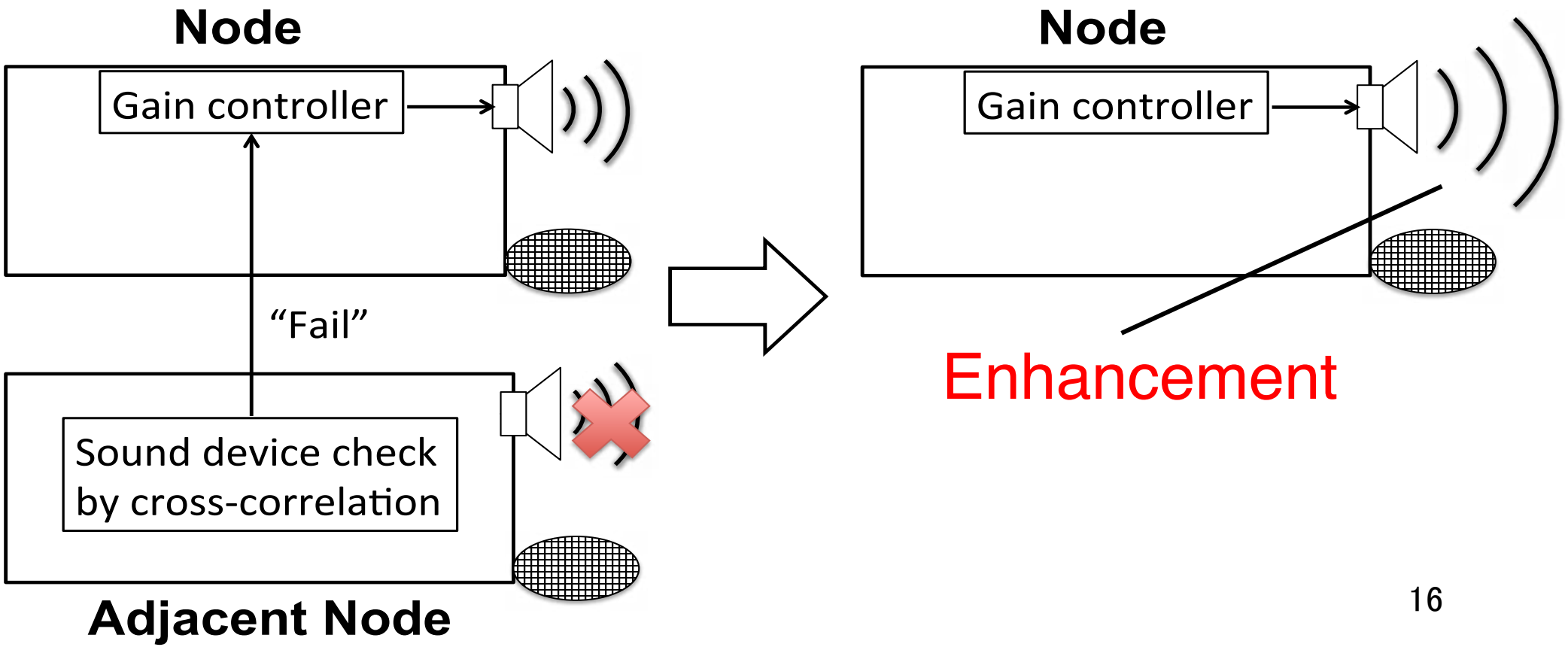
Functions to increase reliability

- Monitoring own emission and environmental sound
  - Monitoring own daily announcements to check the status of sound output.



Functions to increase reliability

- Emission sound level enhancement
  - Status of sound output is shared with other nodes.
  - If sound output of the adjacent node is down, the node increases its emission sound level.



Introduction

- Previous study

  - Estimation of time difference of arrivals between direct sound and reflected sounds using time-frequency information of a single-channel signal. *Acoust. Sci. & Tech.* (in press).

  - did not take into account the attenuations due to
    - atmospheric absorption
    - size of obstacles

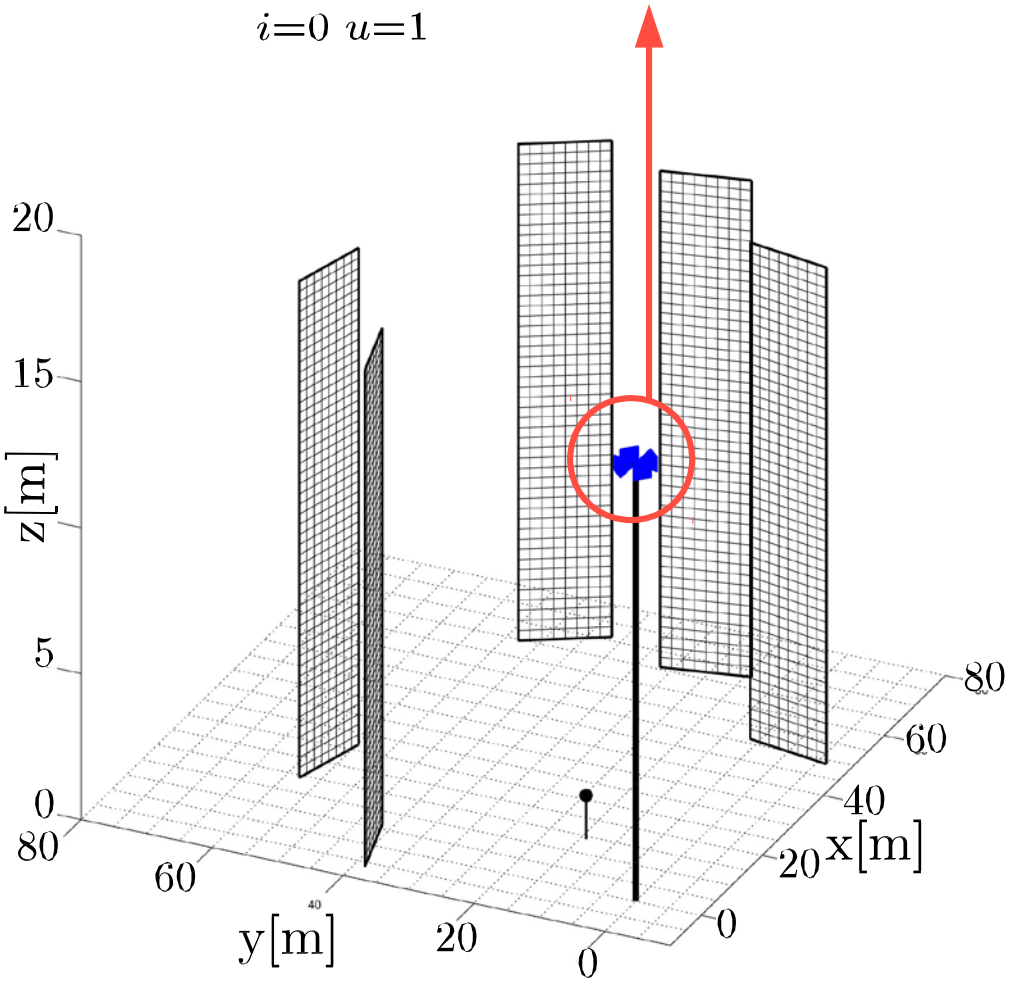
- This paper examines the previous method
  - atmospheric absorption
  - reflections from obstacles

  → ISO 9613-1,2

- Numerical tests of TDOAs estimation
  - to evaluate the performance

Signal Model

$$x(t) = \sum_{i=0}^{I} \sum_{u=1}^{U} g_{i,u}(t) * s(t - r_i/v) + n(t),$$



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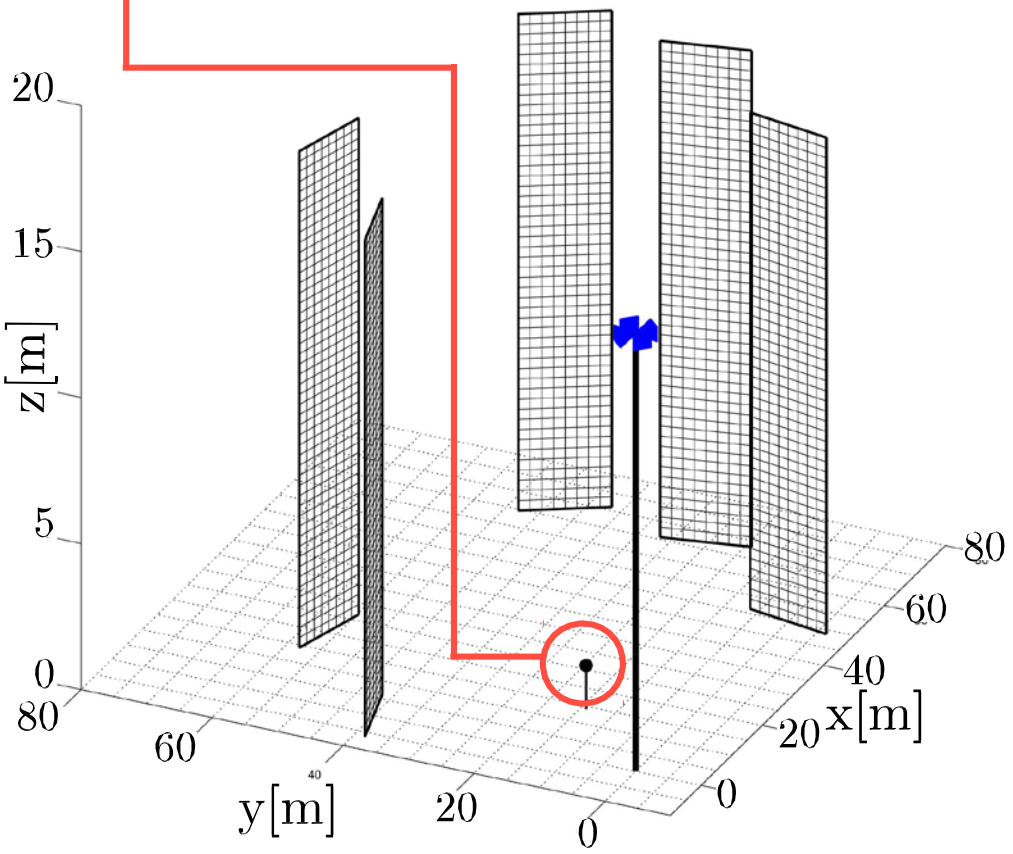
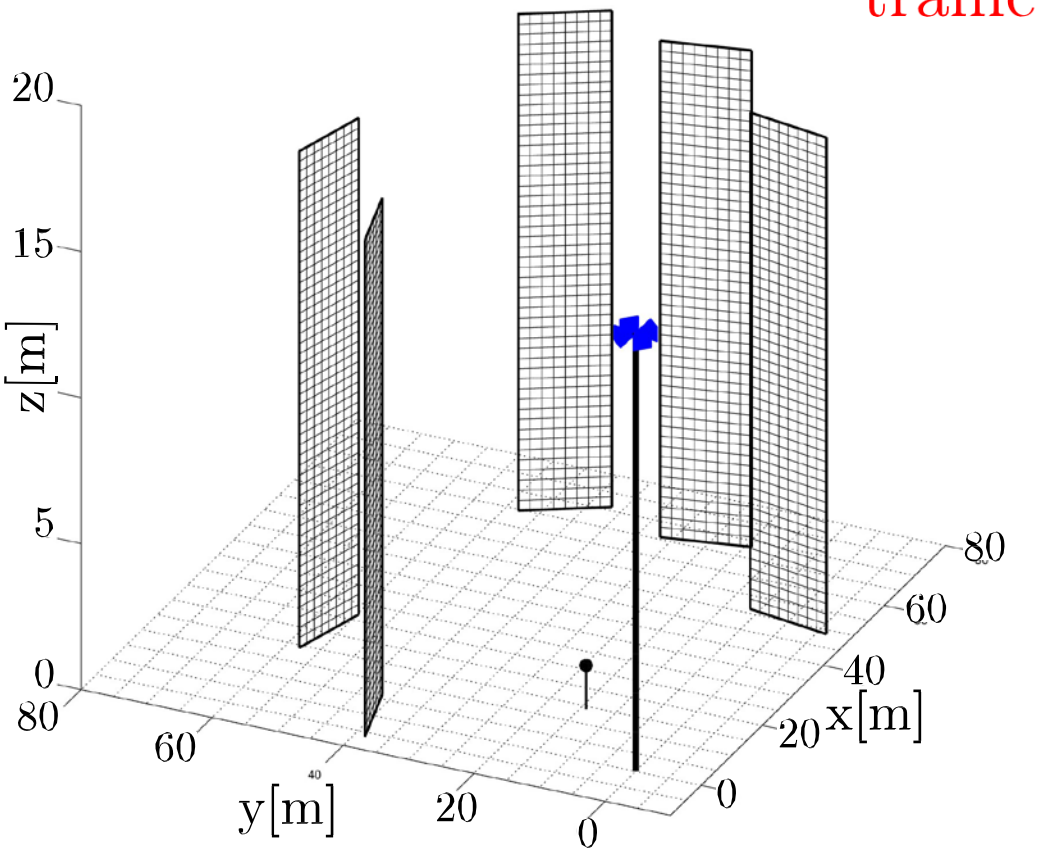


Signal Model

$$x(t) = \sum_{i=0}^{I} \sum_{u=1}^{U} g_{i,u}(t) * s(t - r_i/v) + n(t),$$

traffic noise



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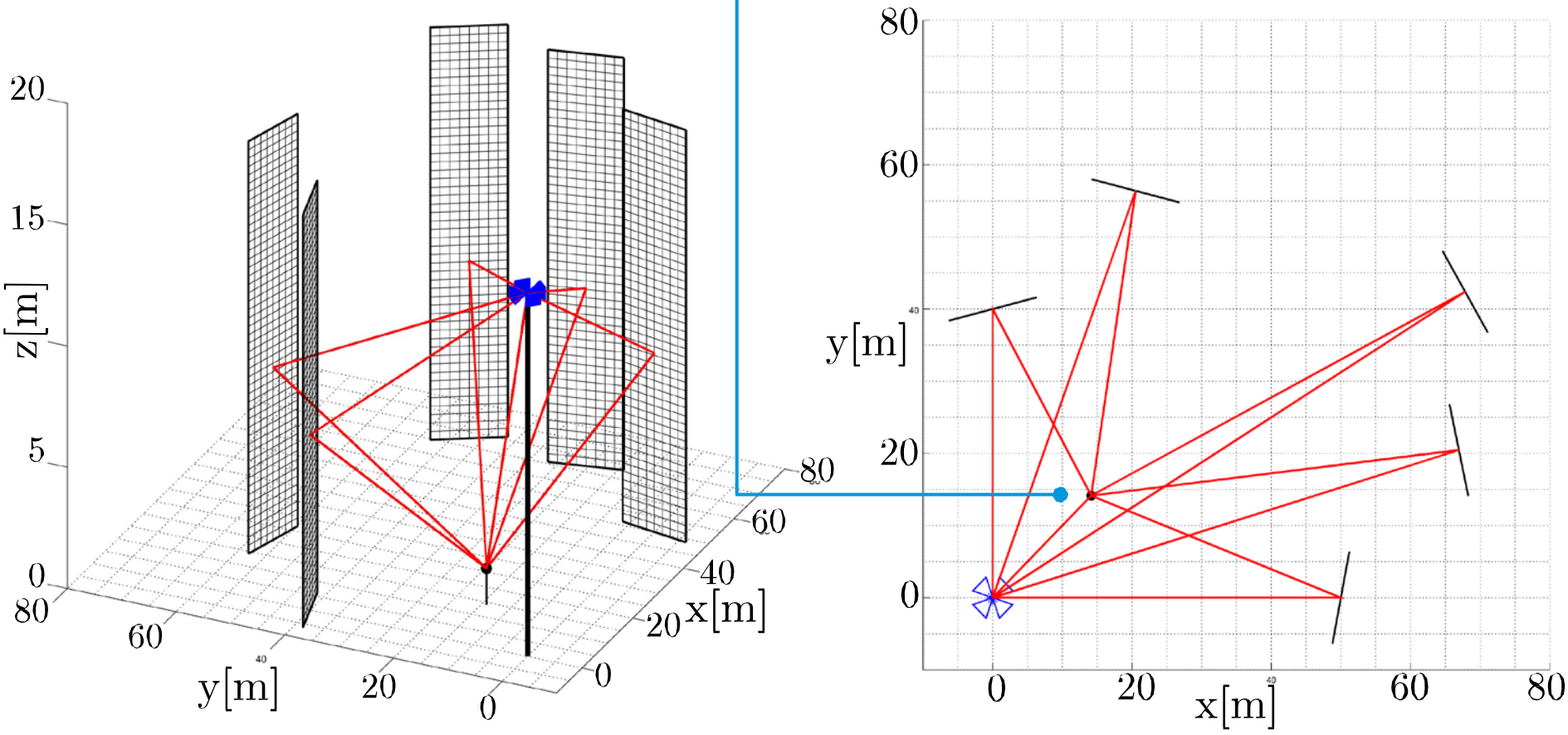
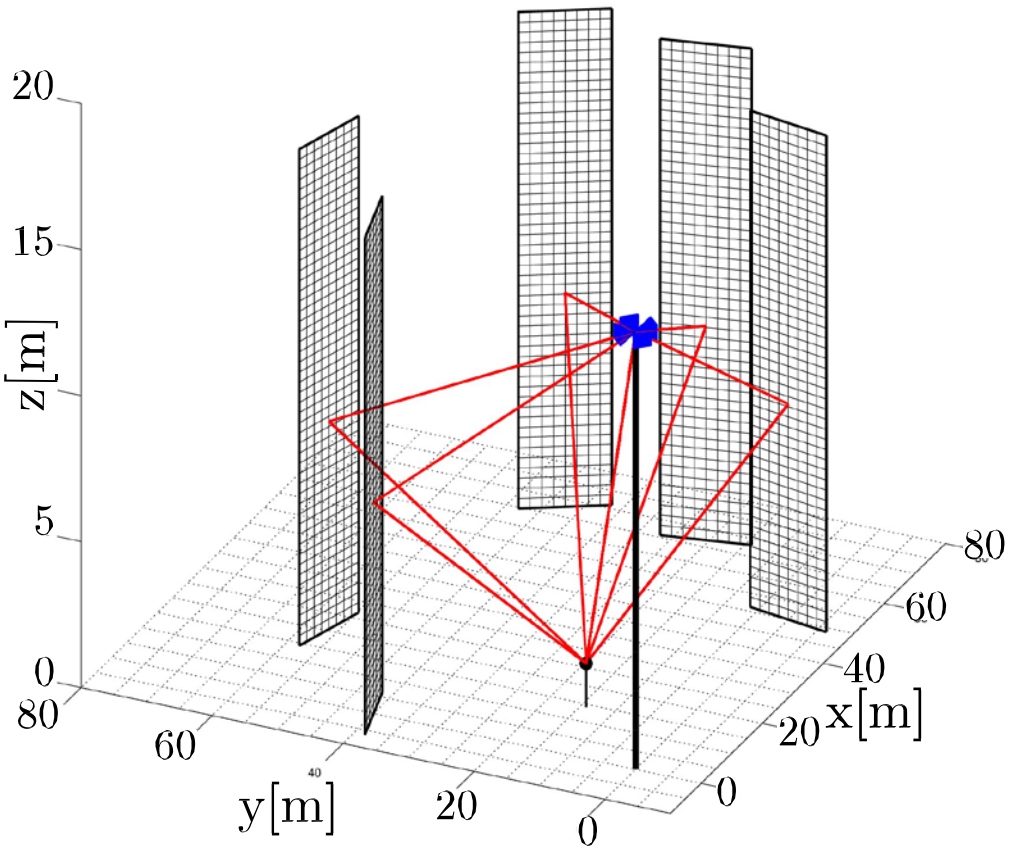


impulse response of
one-third-octave band filter

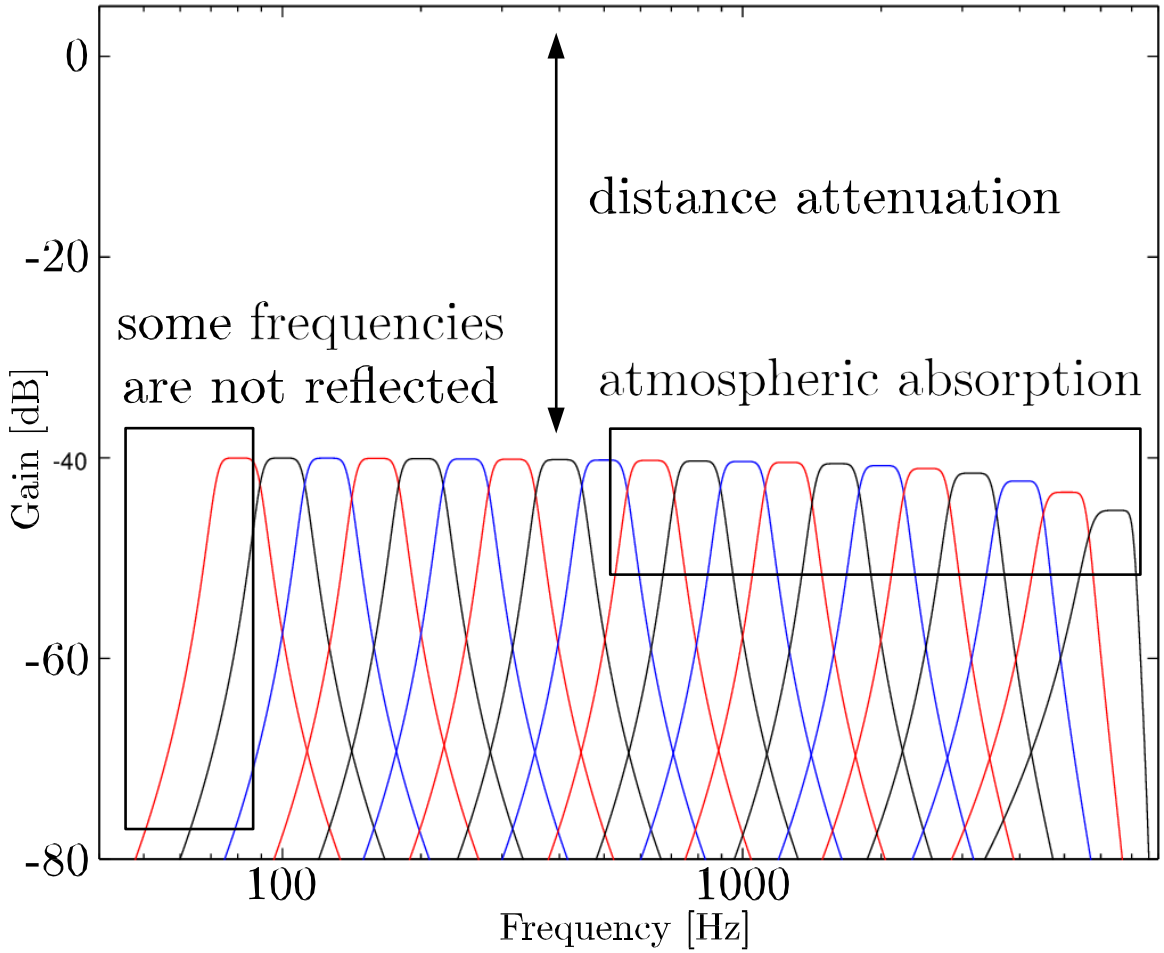
$$x(t) = \sum_{i=0}^{I} \sum_{u=1}^{U} g_{i,u}(t) * s(t - r_i/v) + n(t),$$

Signal Model



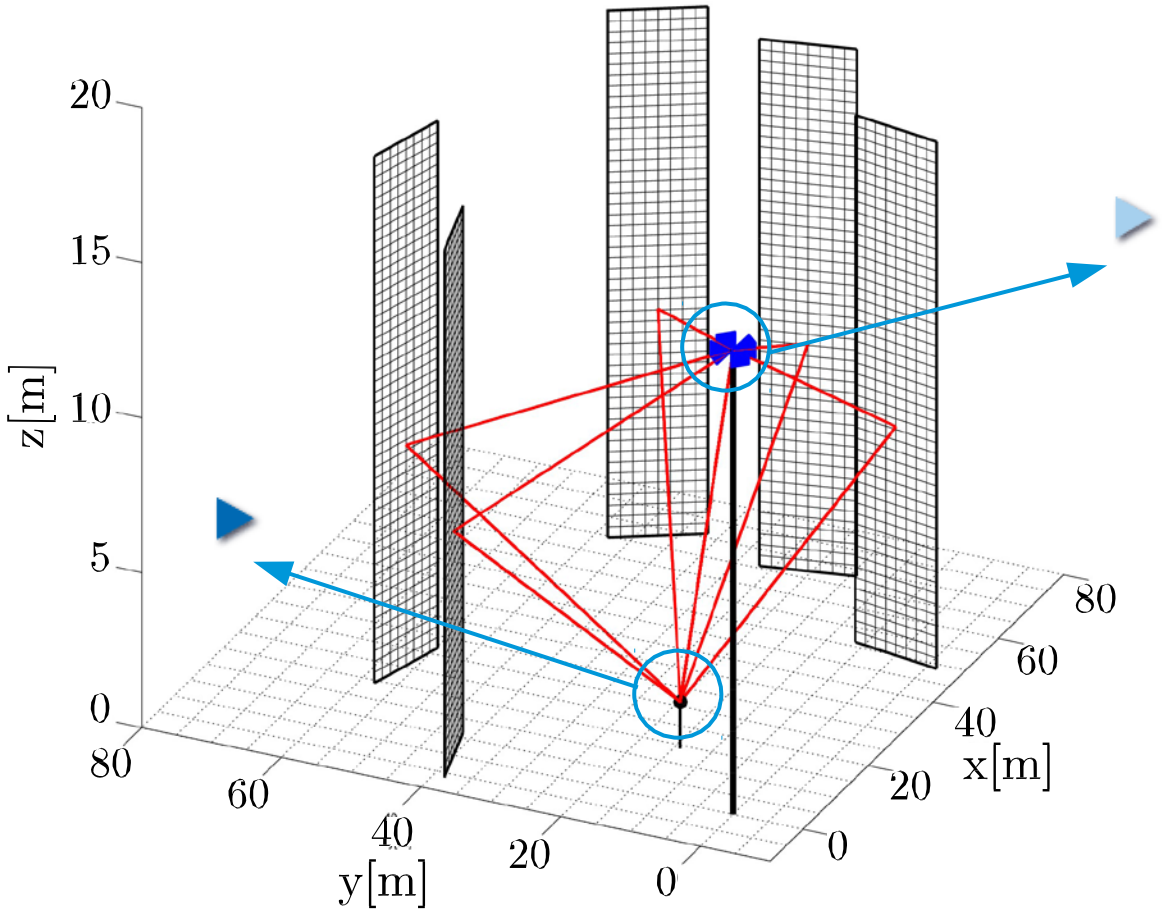
- distance attenuation
- atmospheric absorption
  - air temperature, 15°C
  - relative humidity 73%
  - air pressure 101.325 kPa
- reflection from obstacle
  - sound reflection coefficient is assumed to be 0.8
  - the size of obstacle is large enough compared to wavelength

Signal Model



- third-order Butterworth filter
- ISO 9613 - Part 1 & 2
  - distance attenuation
  - atmospheric absorption
  - reflection from obstacle
- filter bank
  - to imiate a reflected sound

Signal Model



Method

(1) TDOAs estimation

- to extract peaks indicating TDOAs from a single channel signal

(2) Peak identification process

- to provide a better visualization
- to easily identify and obtain peaks

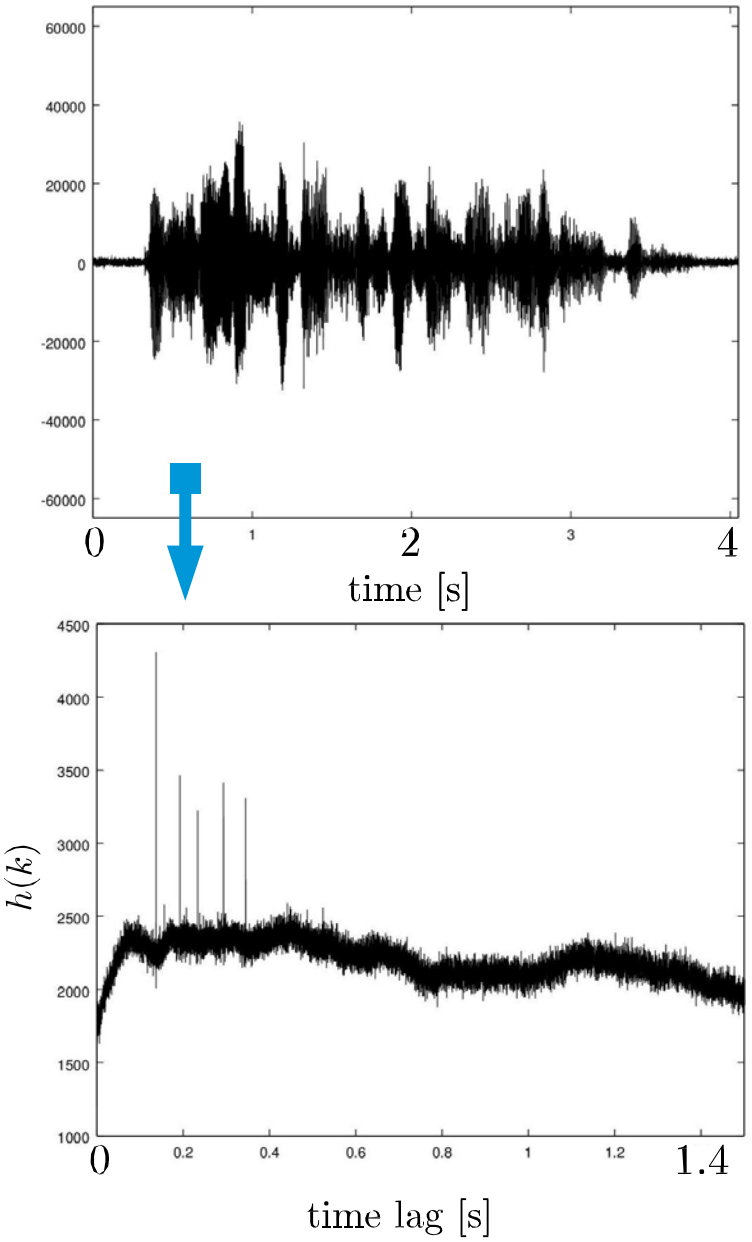
(1) TDOAs estimation

- to find TDOAs, we introduce and define

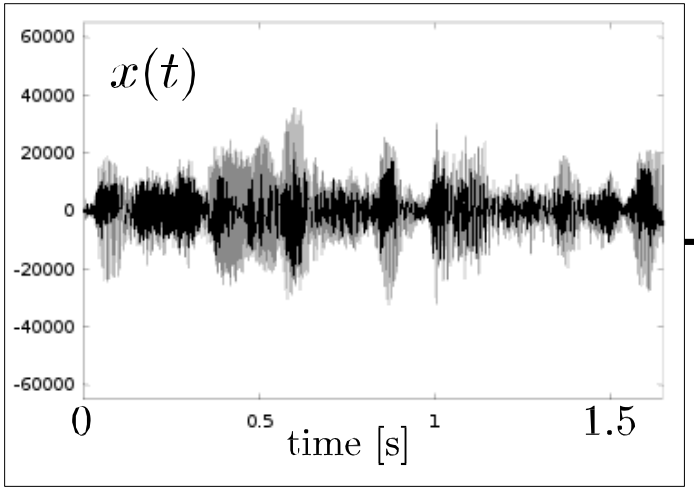
$$h(k) = \sum_{\omega} \sum_{\tau} l_k(\tau, \omega),$$

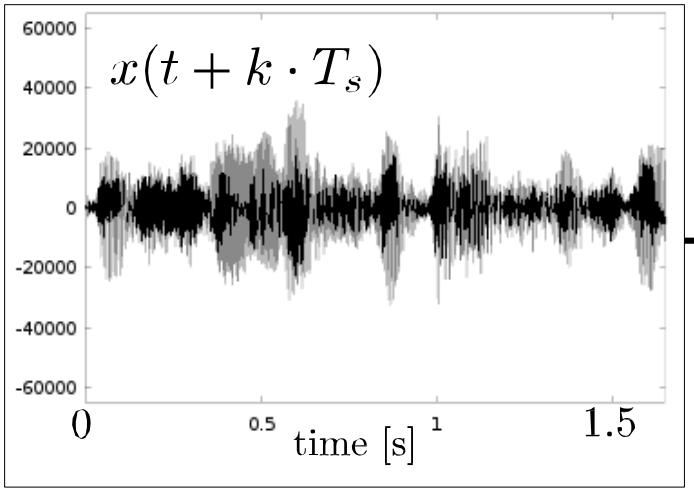
- $$l_k(\tau,\omega) = \begin{cases} 1, & \text{if } \left(\dfrac{X(\tau + k \cdot T_s, \omega)}{X(\tau,\omega)} \in \mathbb{R}\right) \\ & \wedge \left(20 \log_{10} |X(\tau + k \cdot T_s, \omega)| > \gamma_{\text{th}}\right) \\ & \wedge \left(20 \log_{10} |X(\tau,\omega)| > \gamma_{\text{th}}\right) \\ 0, & \text{otherwise} \end{cases}$$

  - $X(\tau + k \cdot T_s, \omega)$ is the STFT of $x(t + k \cdot T_s)$
  - T_s is the sampling period
  - γ_{th} is the background noise level in dB



TDOAs Estimation





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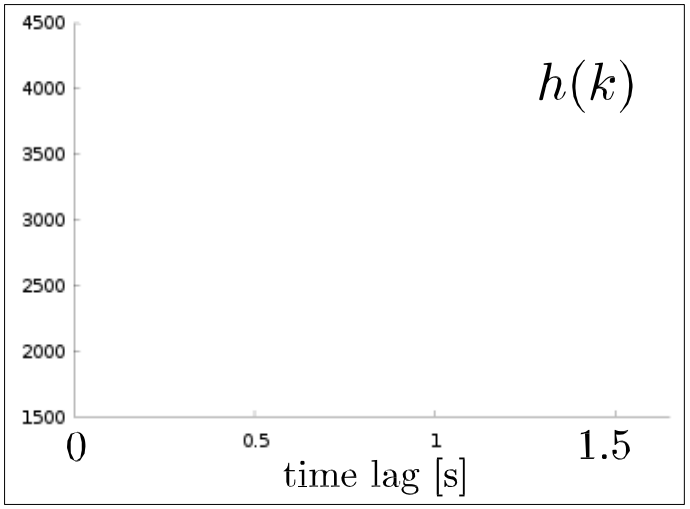

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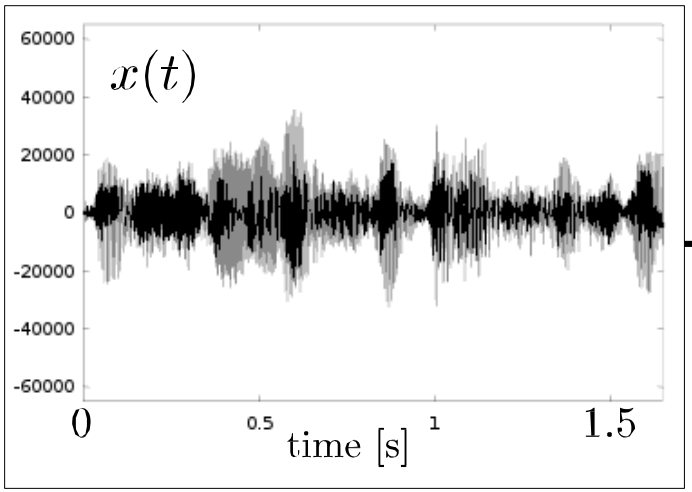

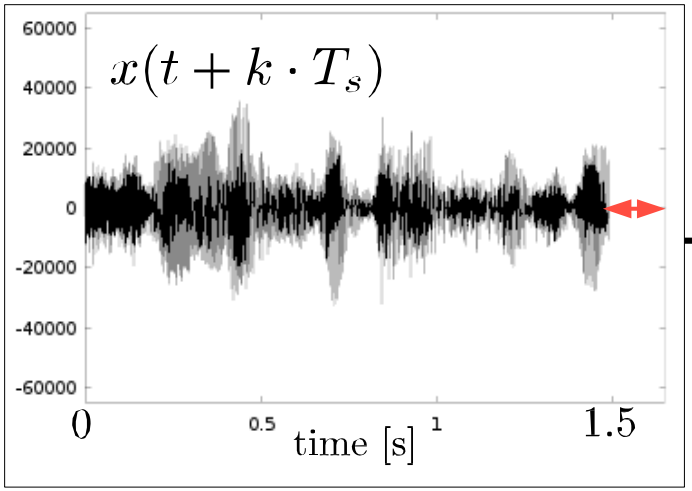

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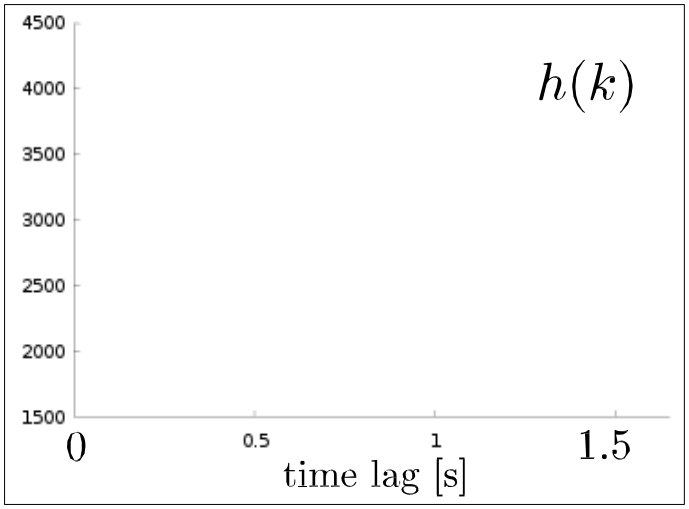

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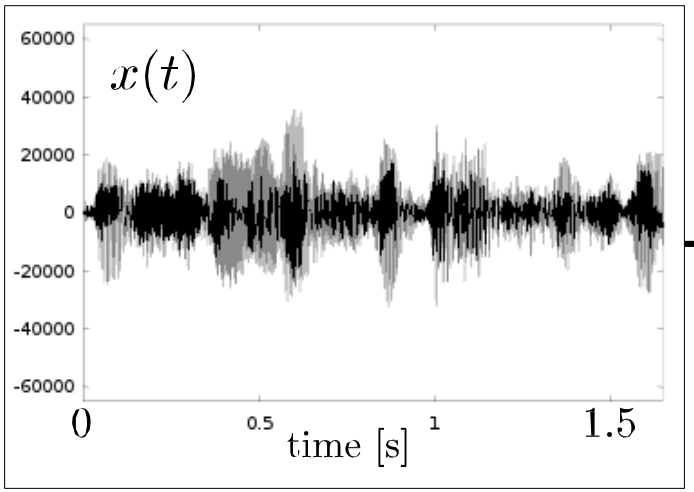

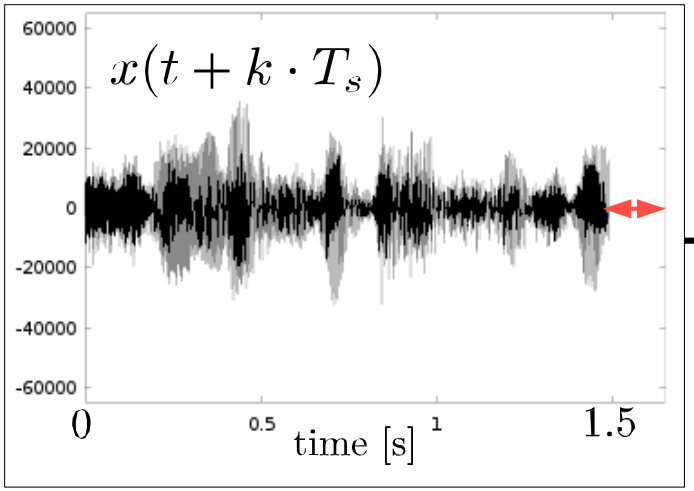

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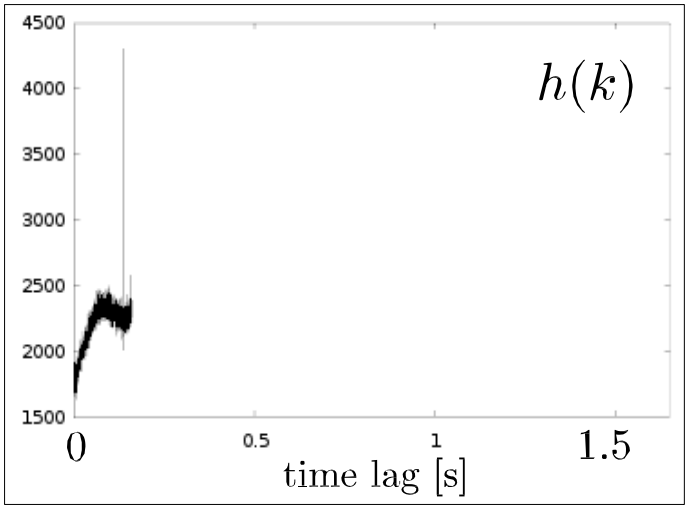

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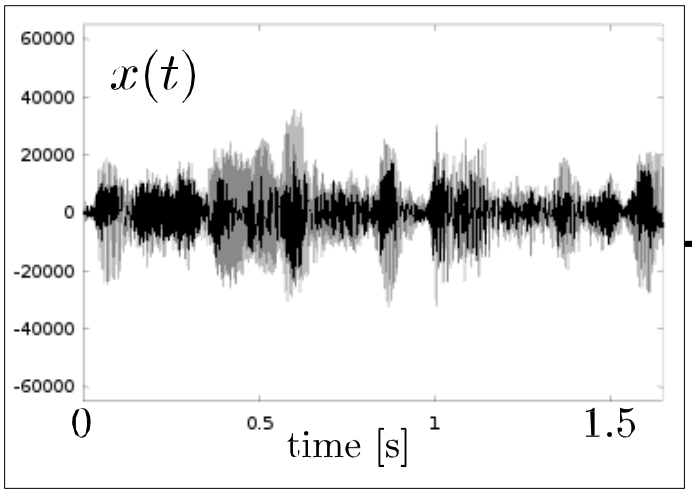

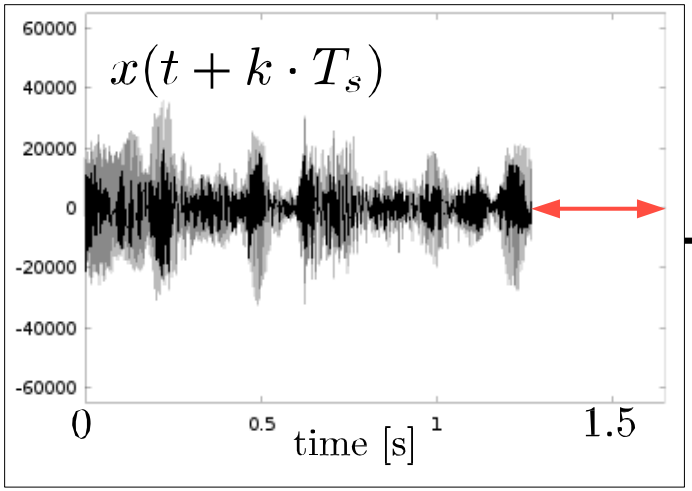

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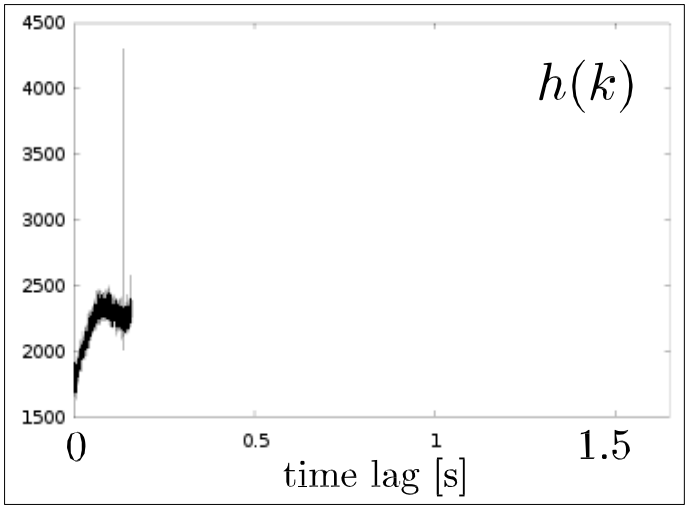

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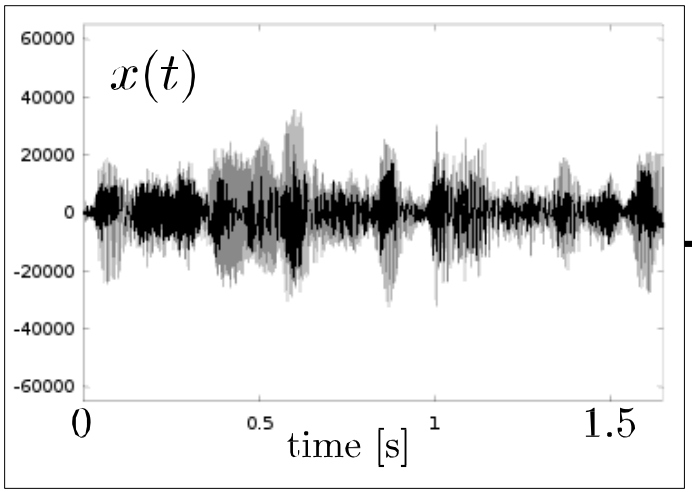

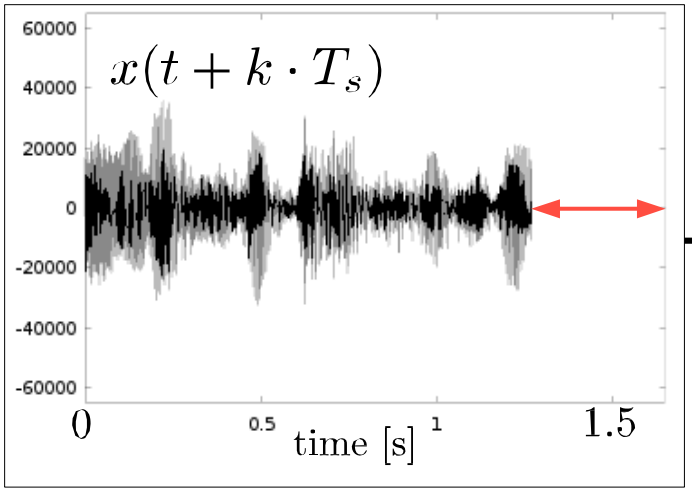

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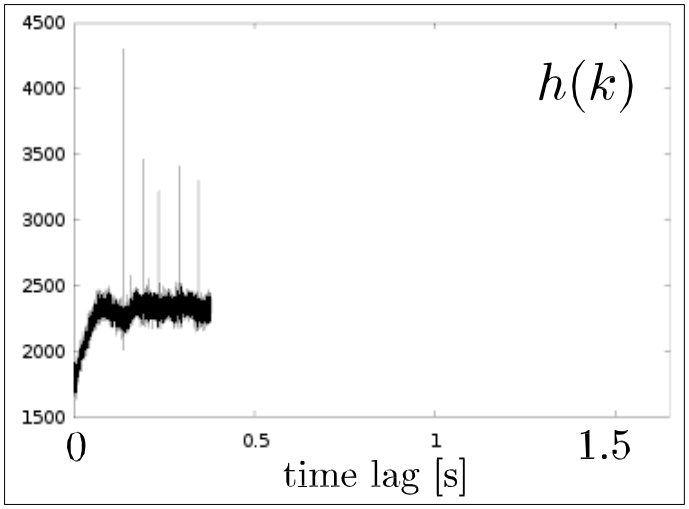

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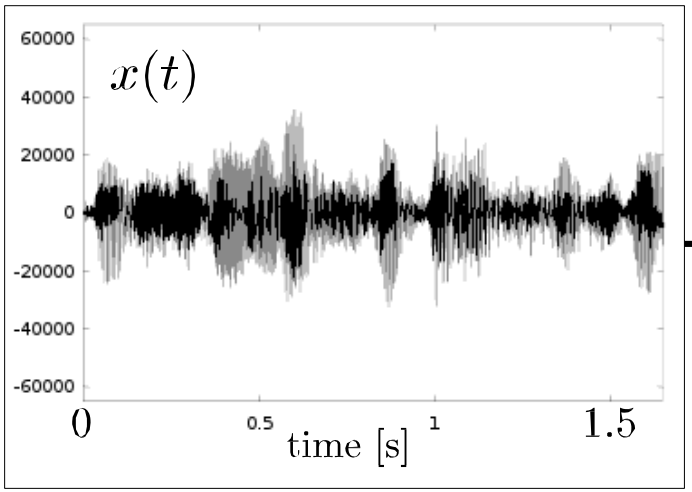

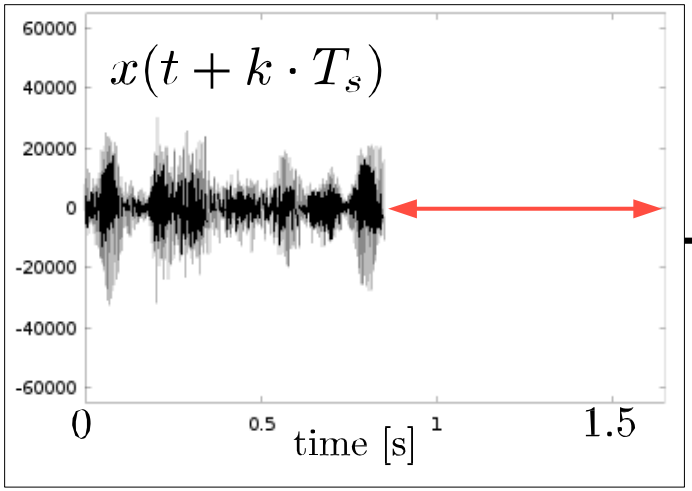

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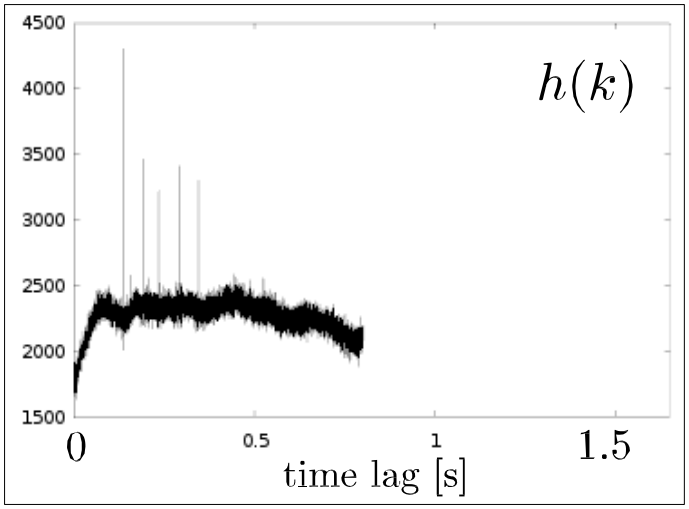
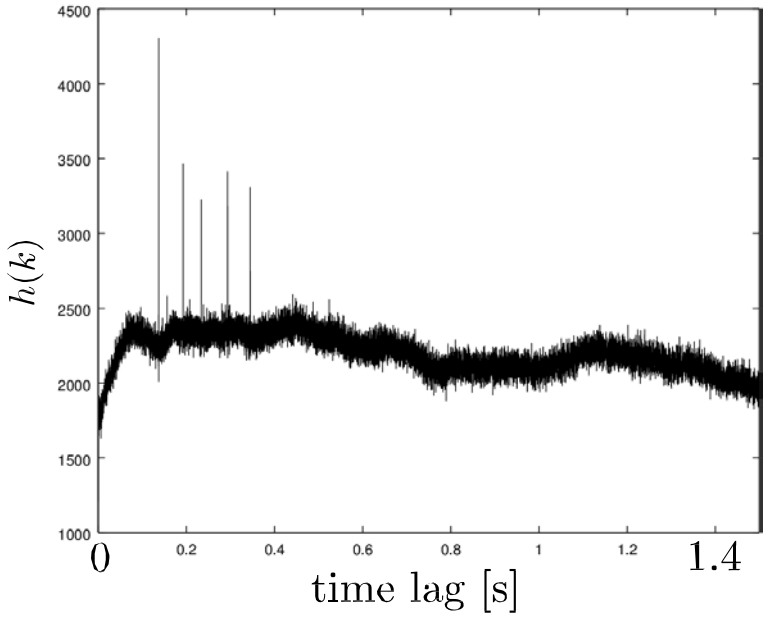
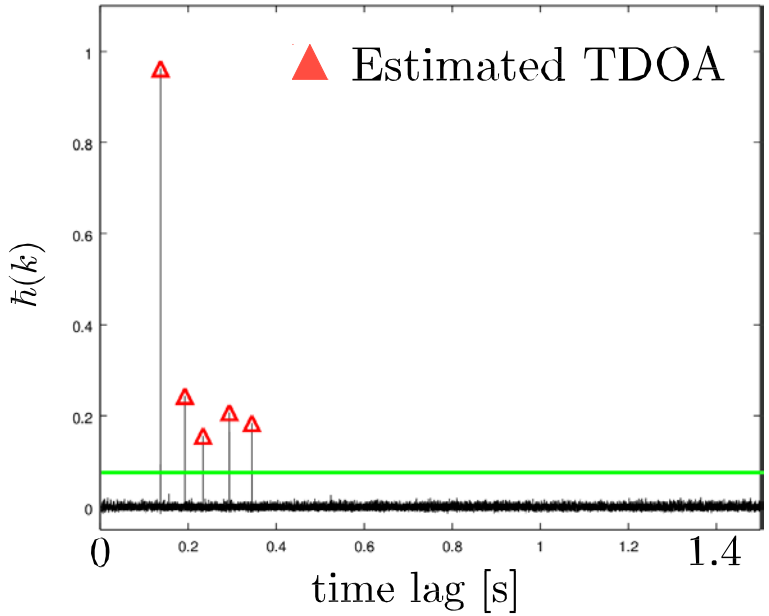


(2) Peak Identification Process

- $h(k)$ is divided into groups
- the data in each group are divided by the median value
- all groups are merged into the original size which is denoted as $g(k)$
- $\hbar(k) = \left(\frac{g(k)}{\max(g(k))}\right)^{\beta} - \mathrm{E}\left[\left(\frac{g(k)}{\max(g(k))}\right)^{\beta}\right],$
- using a threshold to find peaks



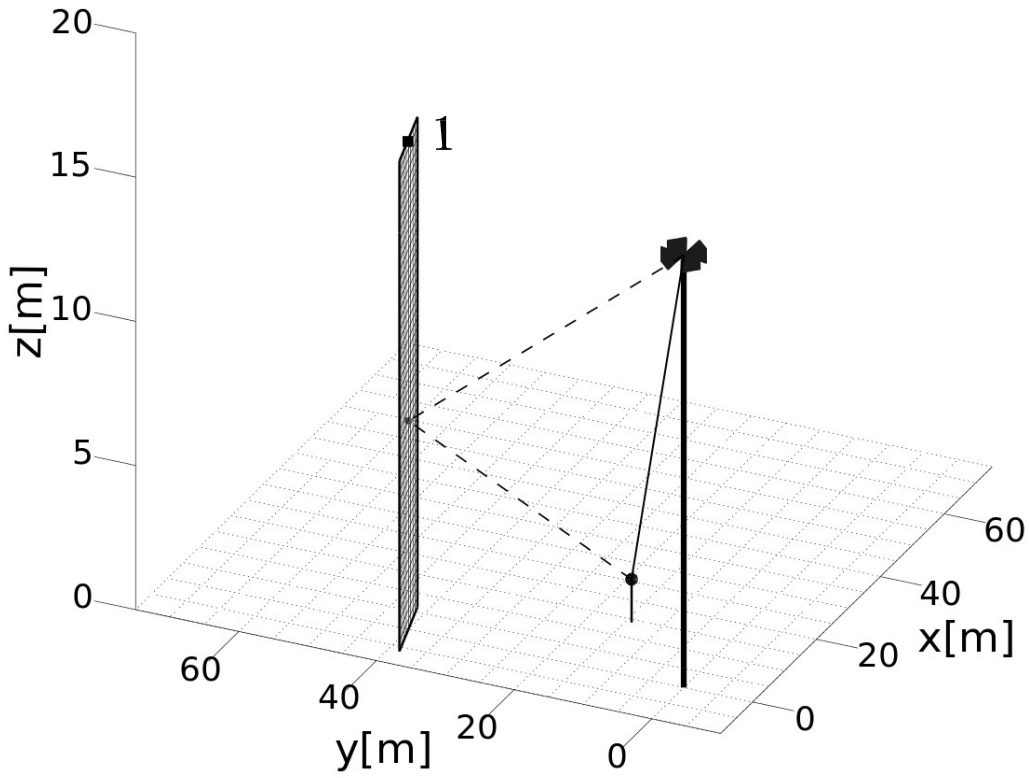


Result Discussion

For evaluation

- Five different cases

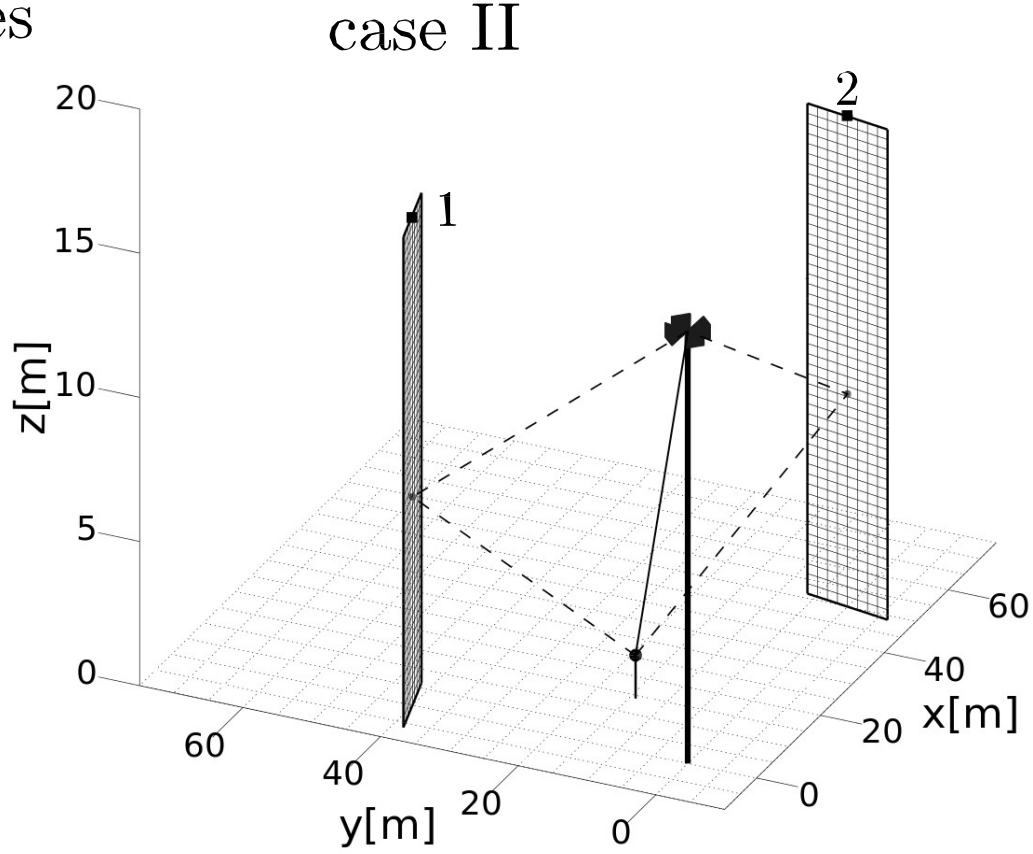
case I



Result Discussion

For evaluation

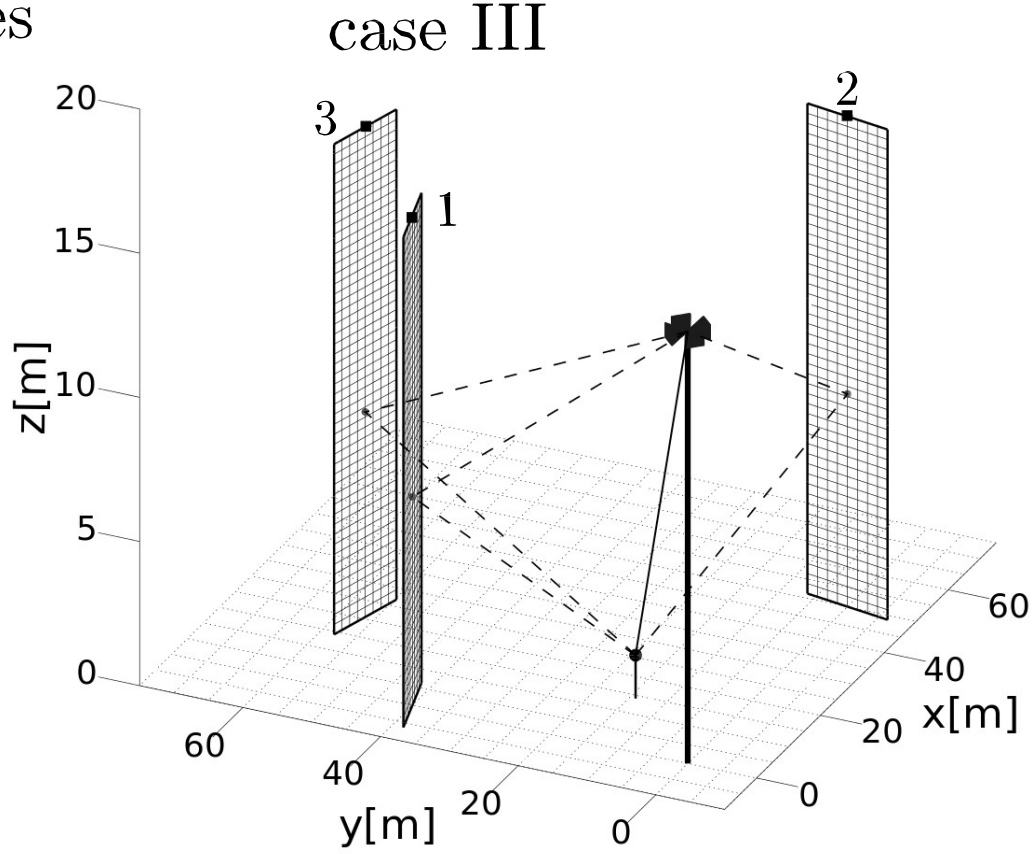
- Five different cases



Result Discussion

For evaluation

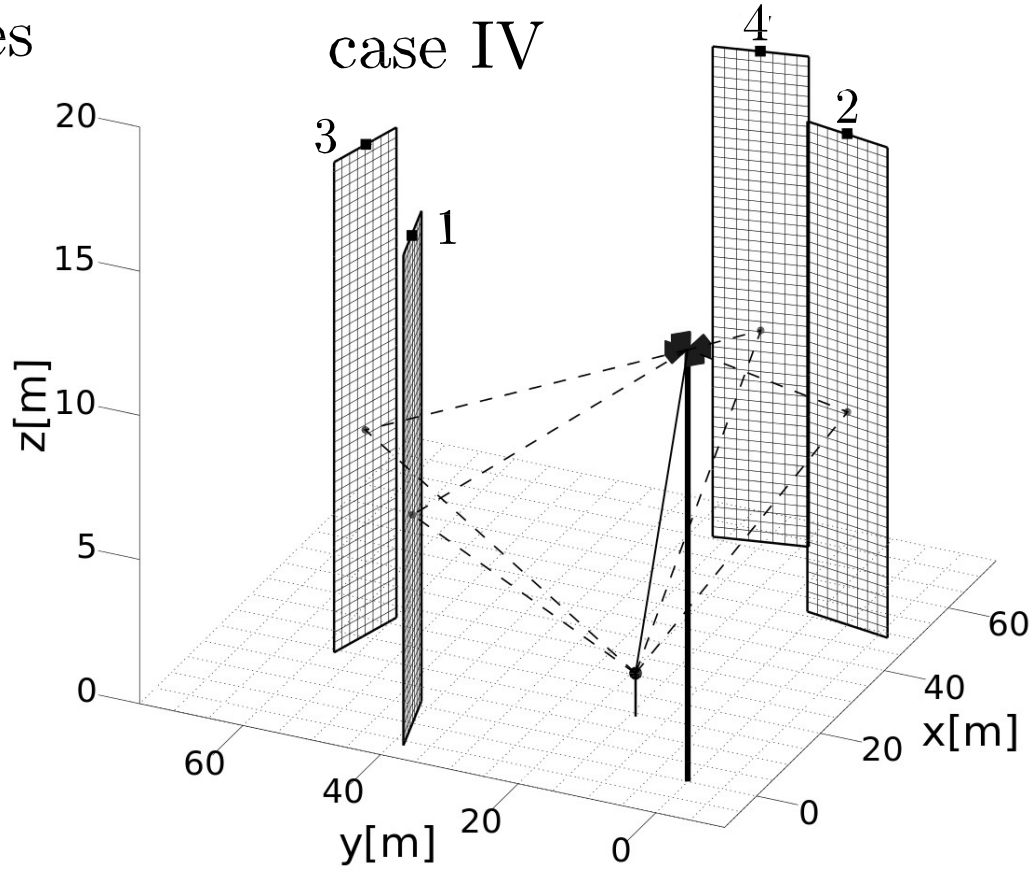
- Five different cases



Result Discussion

For evaluation

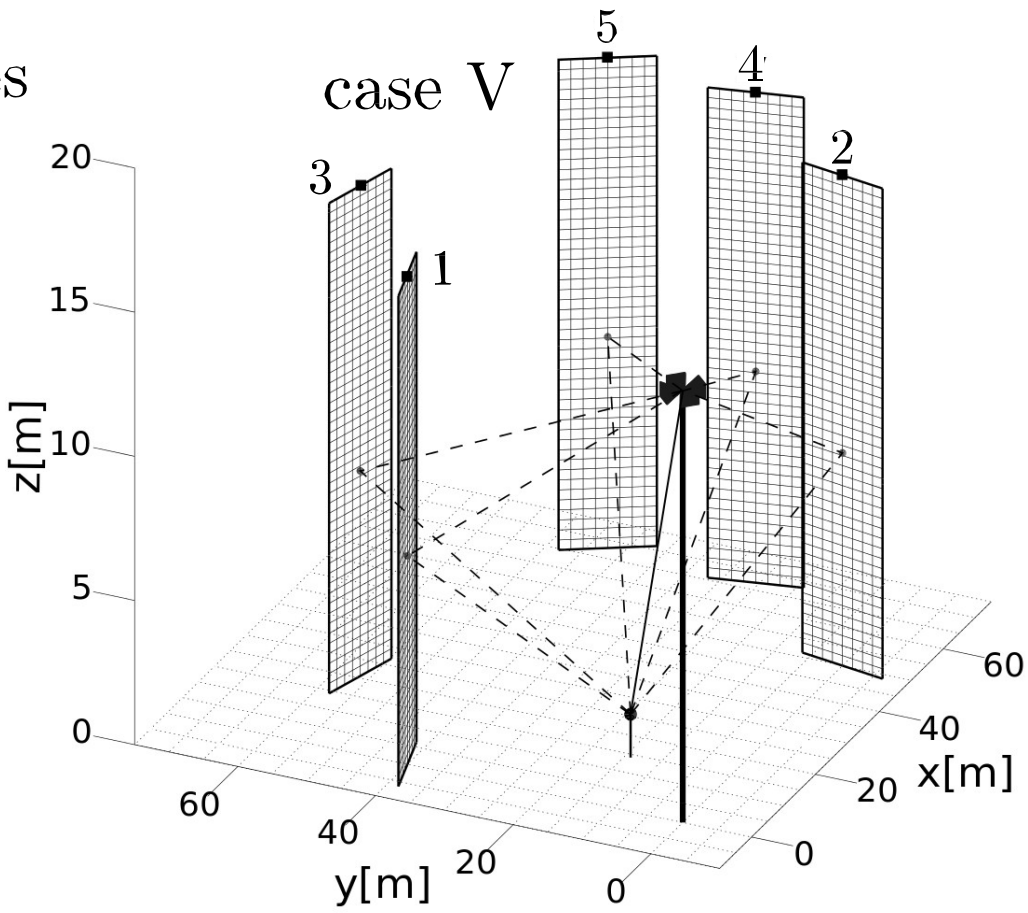
- Five different cases



Result Discussion

For evaluation

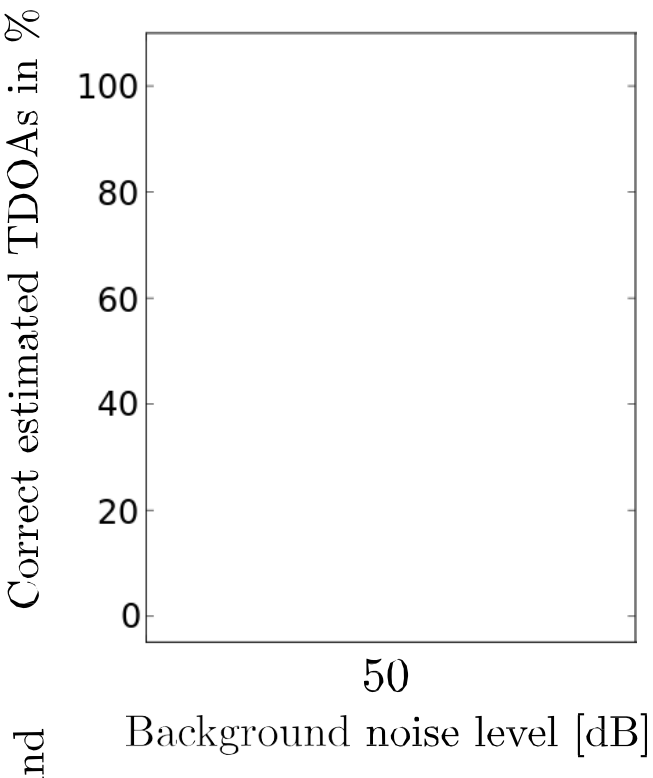
- Five different cases

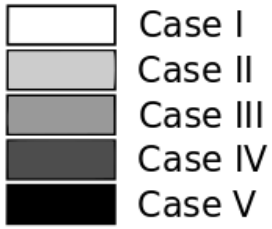


Result Discussion

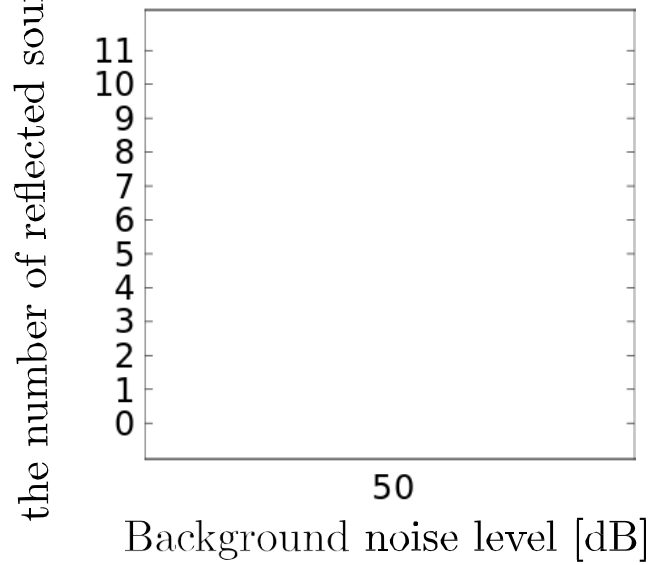
For evaluation

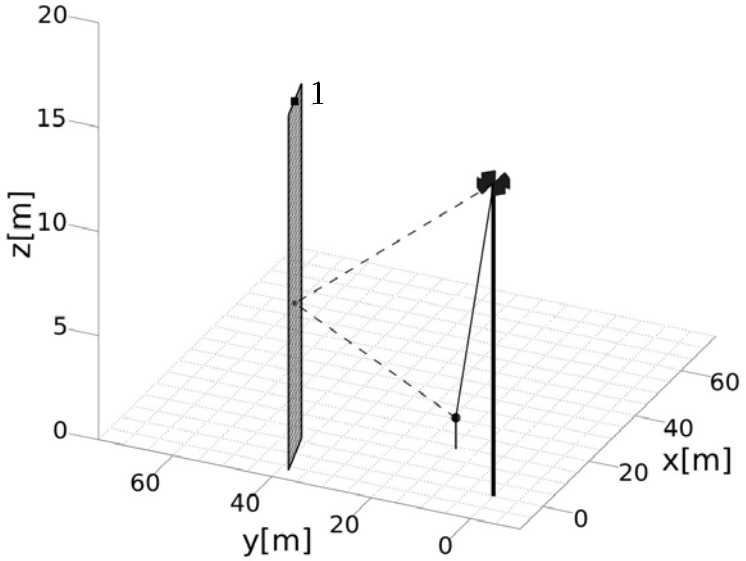
- Five different cases
- Evaluation criteria
  - the percentage of correct estimated TDOAs
  - histogram of the number of reflected sound

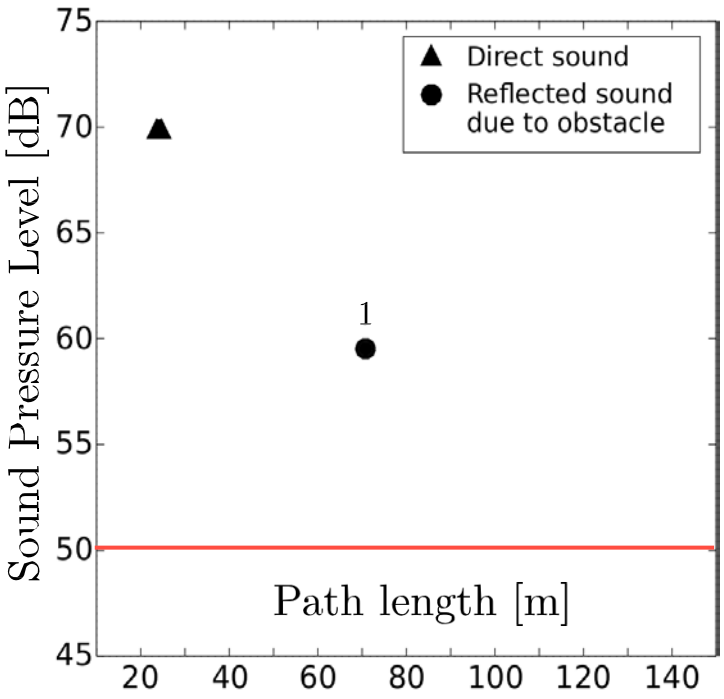


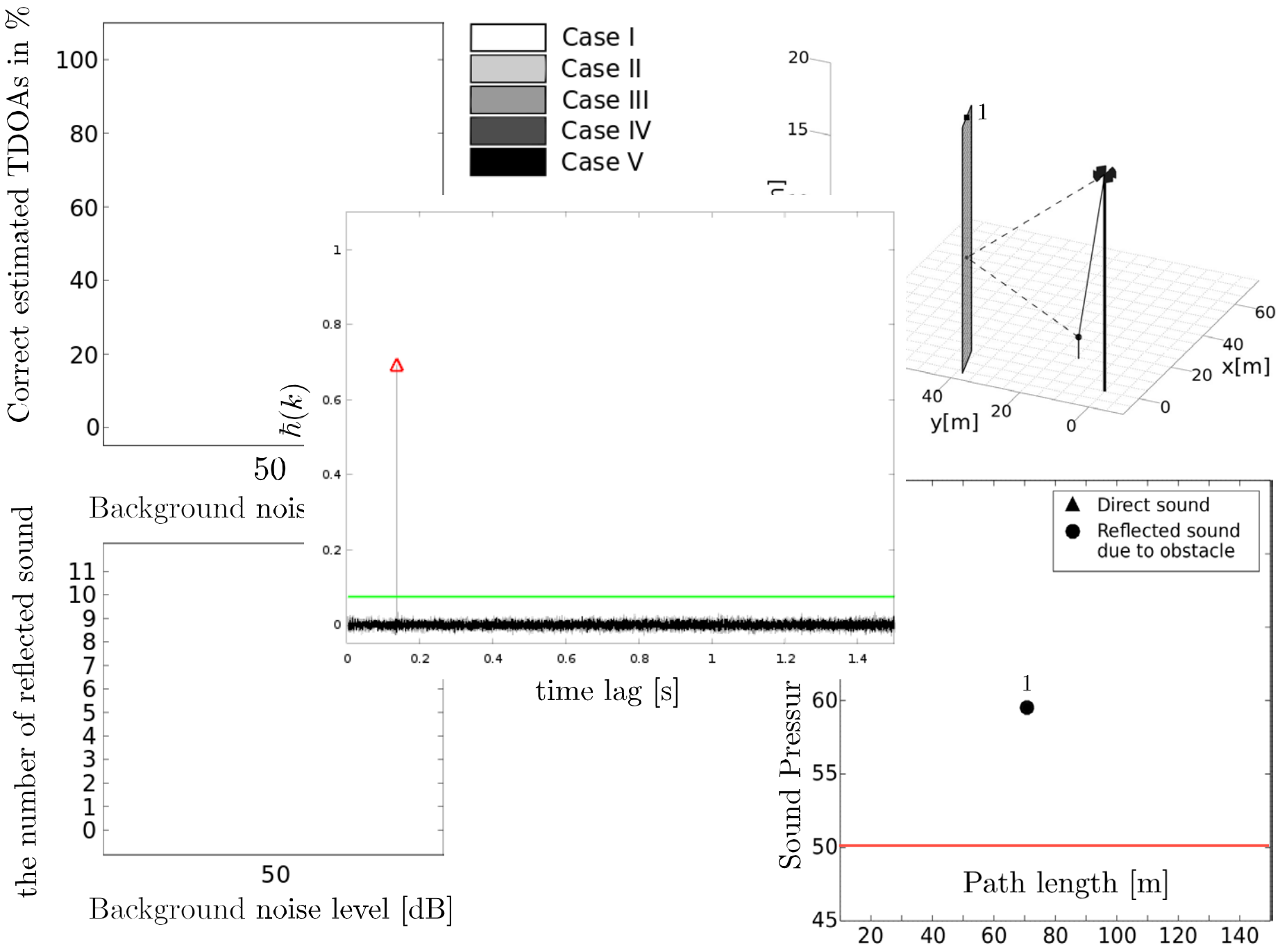


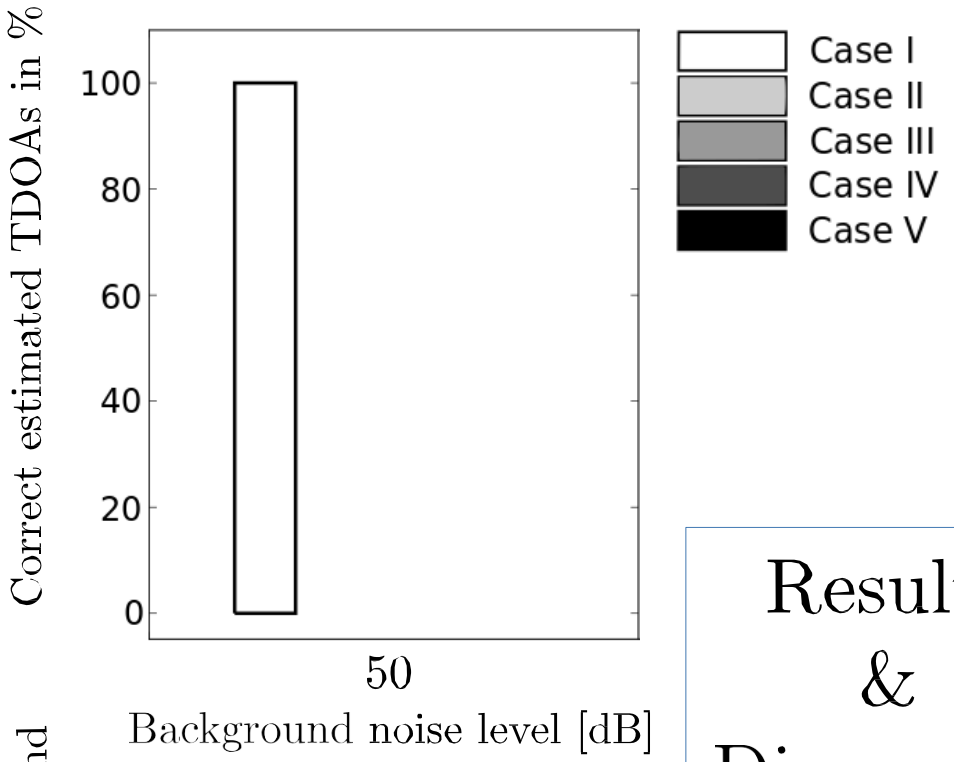
Results & Discussion



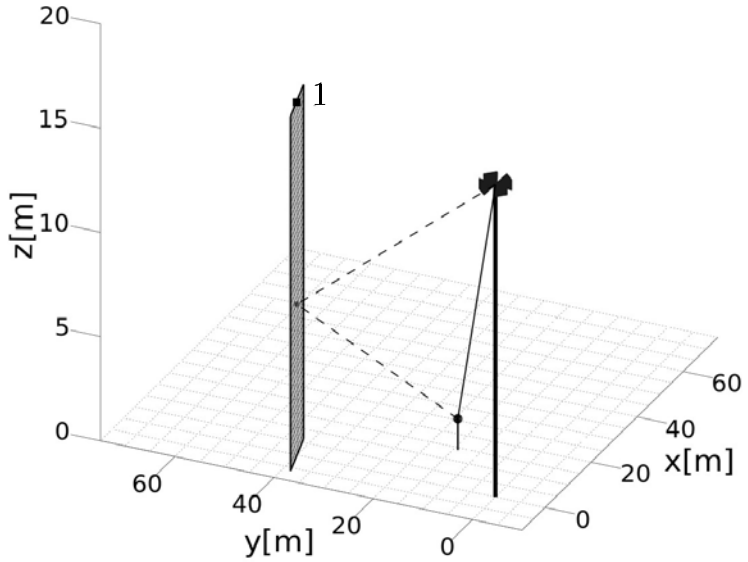


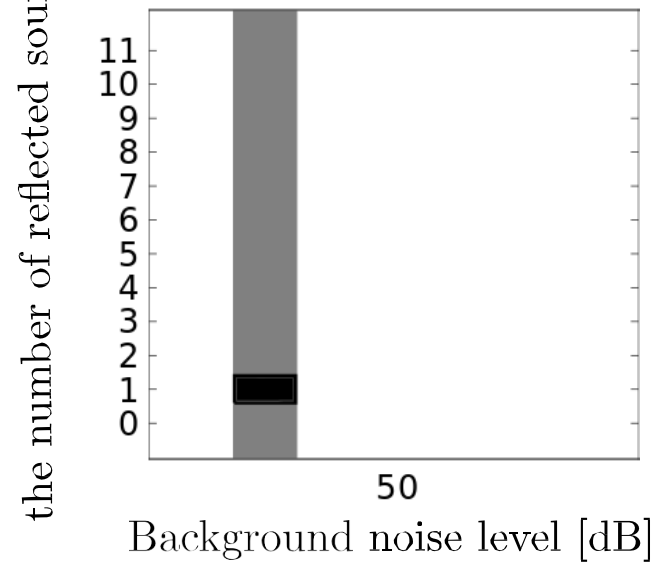


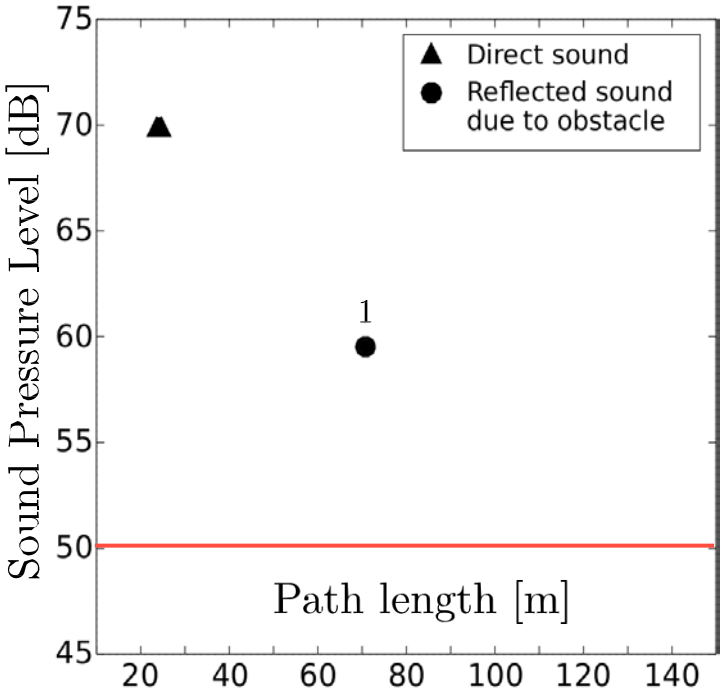

Correct estimated TDOAs in %
Case I
Case II
Case III
Case IV
Case V
Background nois
the number of reflected sound
Background noise level [dB]
time lag [s]
Direct sound
Reflected sound due to obstacle
Sound Pressur
Path length [m]
y[m]
x[m]

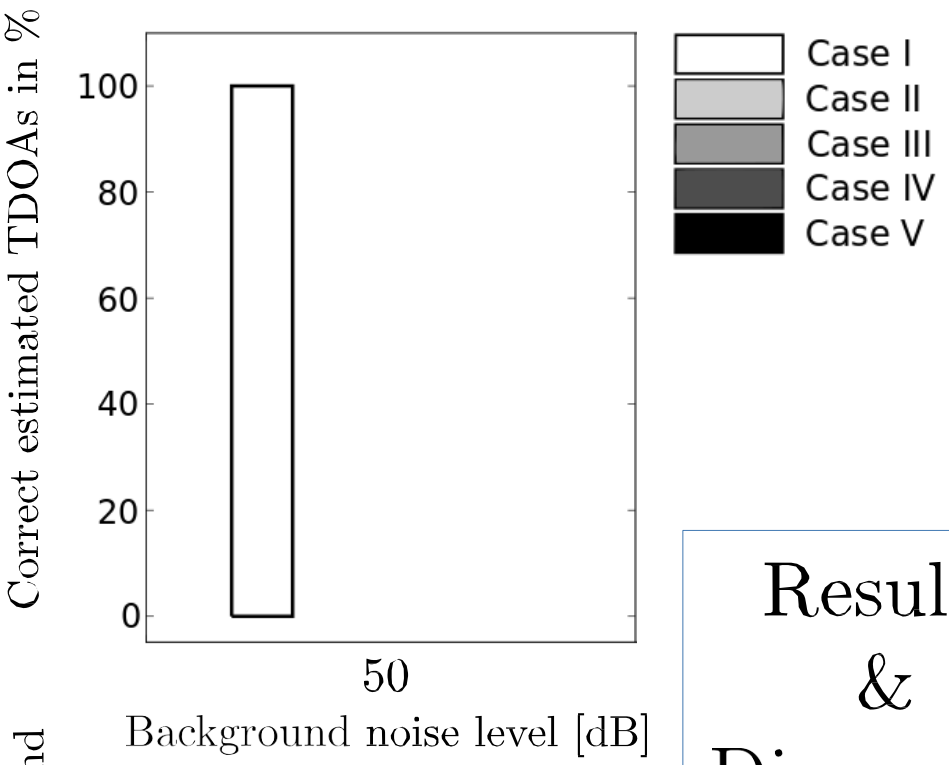


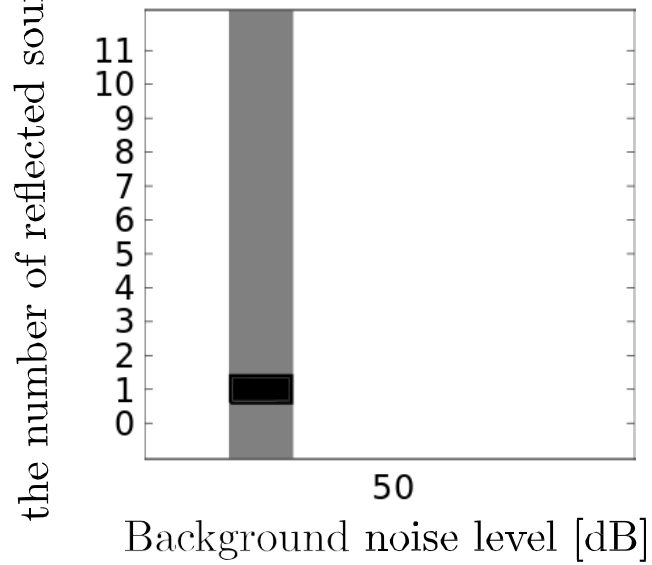
Results & Discussion



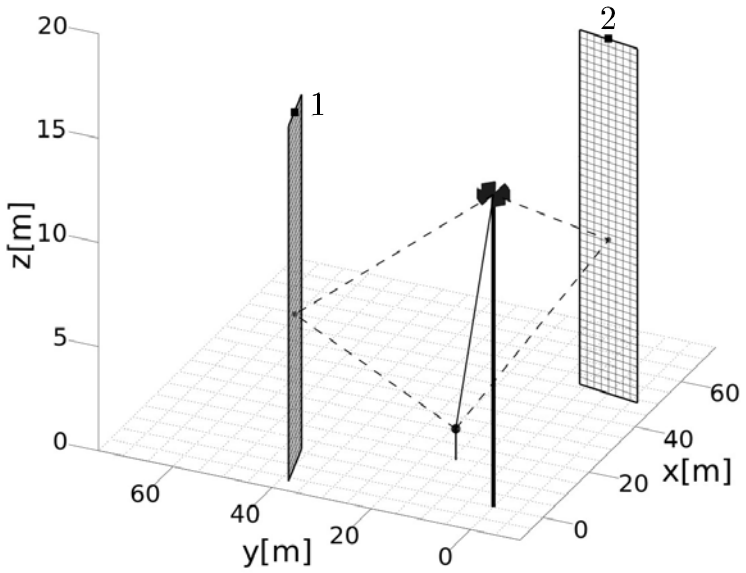


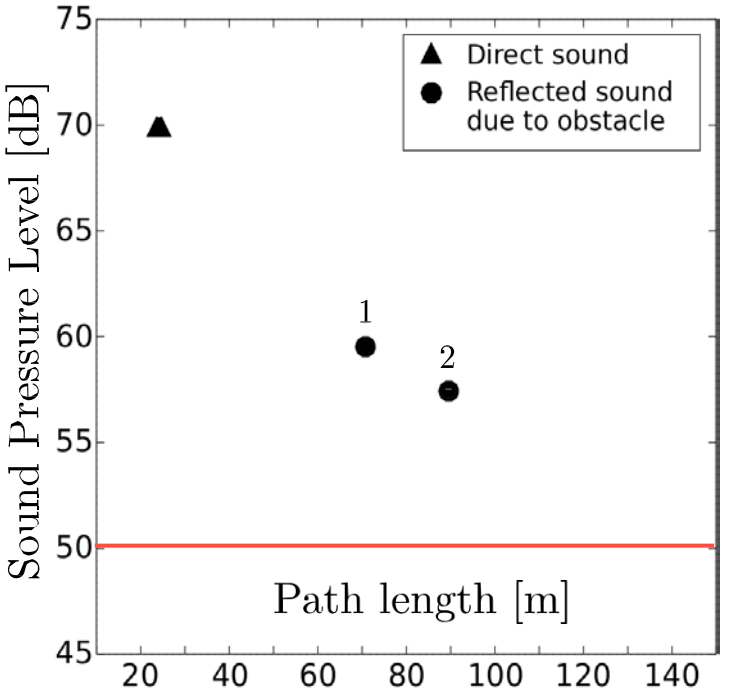


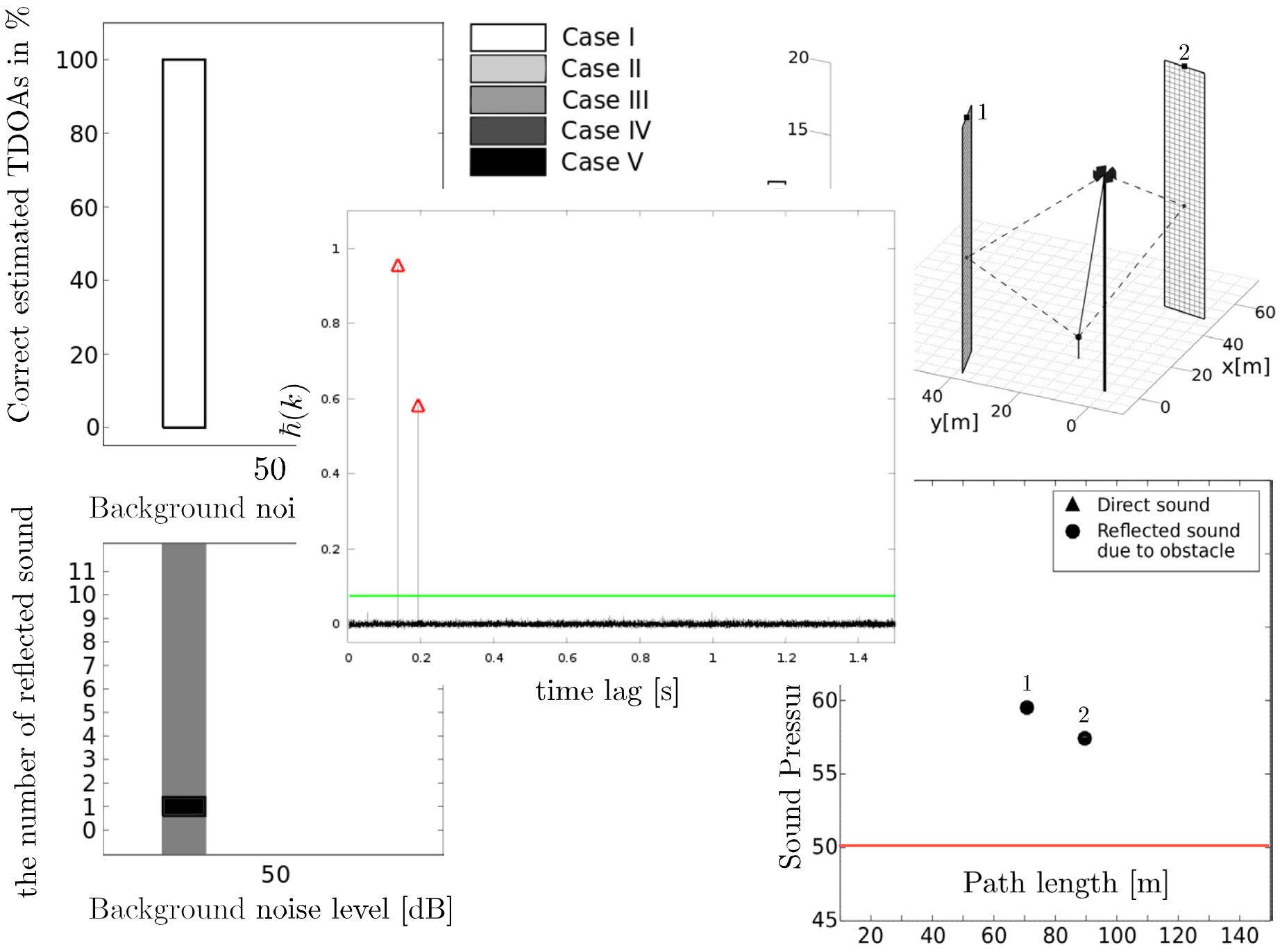


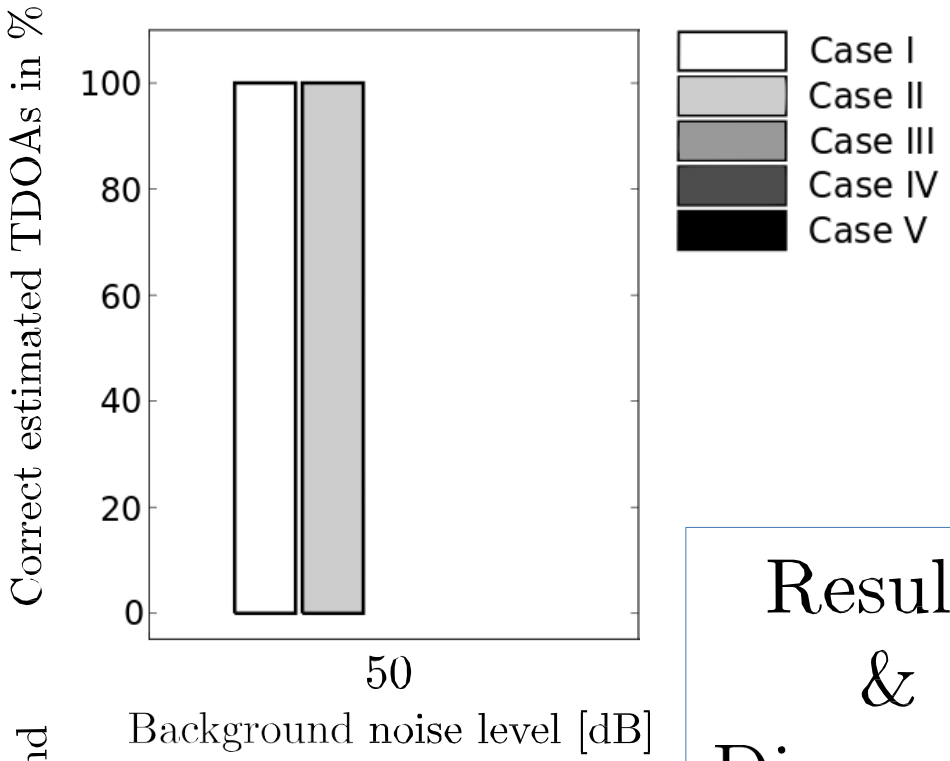


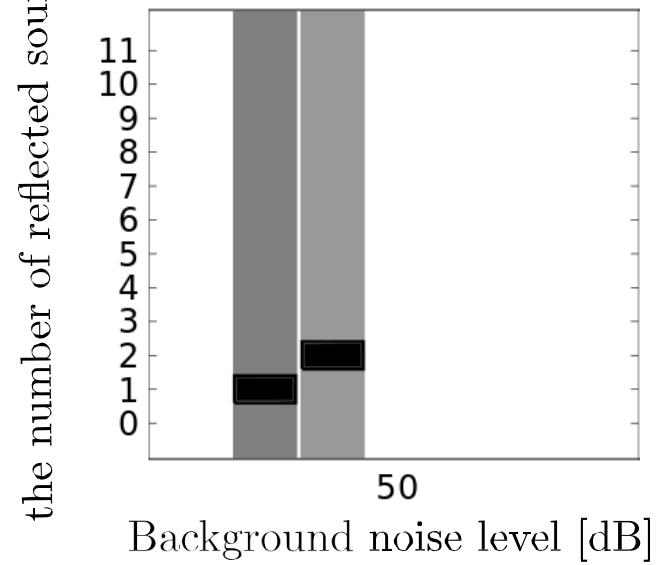
Results & Discussion



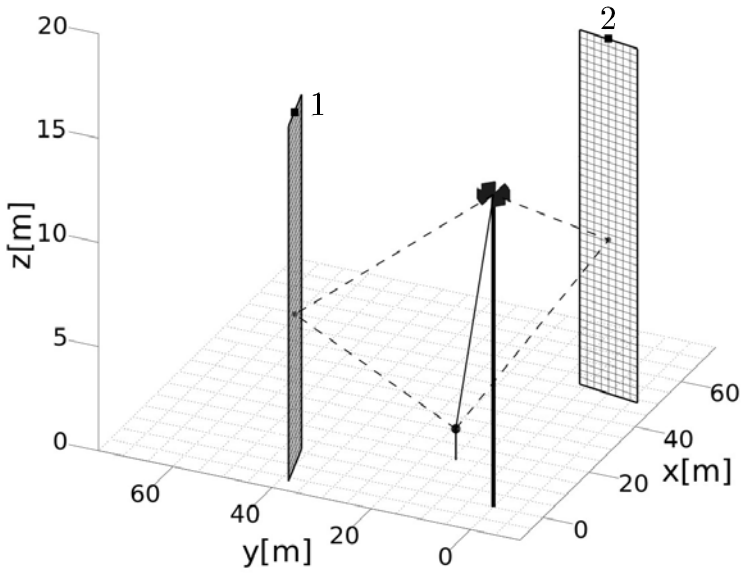


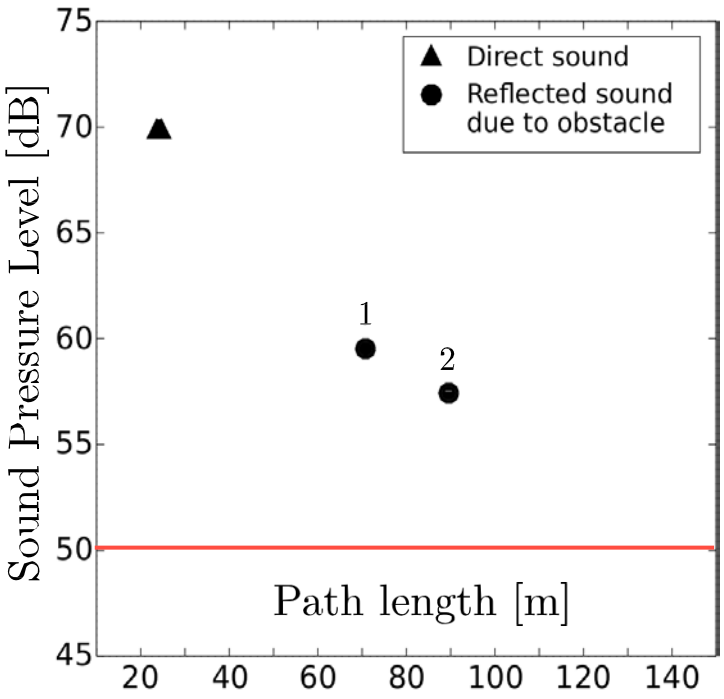

Correct estimated TDOAs in %
100
80
60
40
20
0
50
Background noi
Case I
Case II
Case III
Case IV
Case V
20
15
1
2
60
40
20
x[m]
0
40
y[m]
20
0
$\hbar(k)$
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
time lag [s]
the number of reflected sound
11
10
9
8
7
6
5
4
3
2
1
0
50
Background noise level [dB]
Direct sound
Reflected sound due to obstacle
Sound Pressur
60
55
50
45
1
2
20
40
60
80
100
120
140
Path length [m]

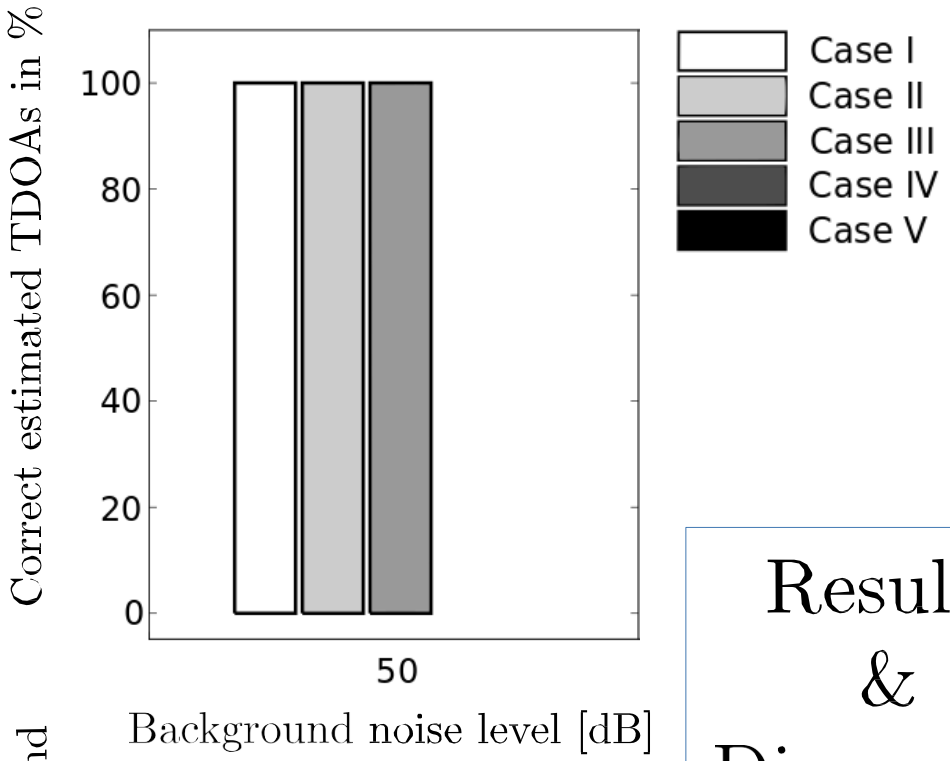


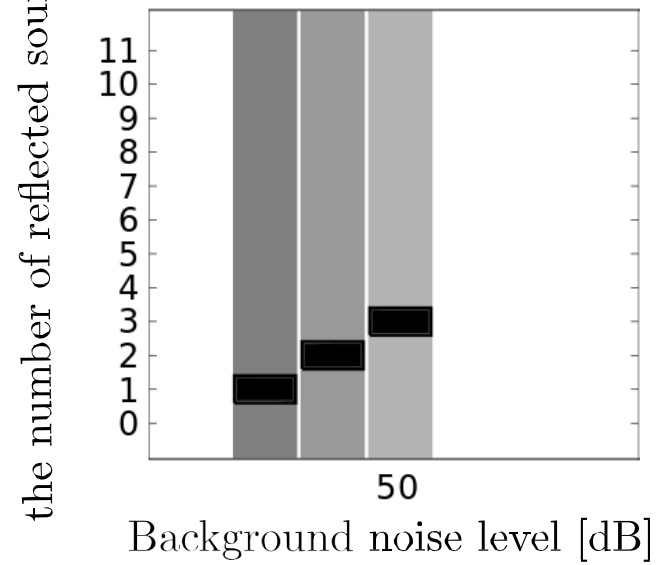


Results & Discussion

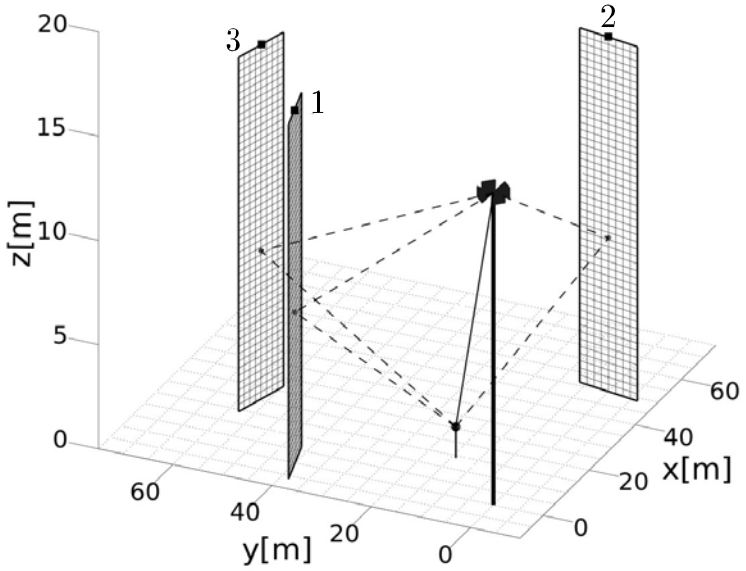


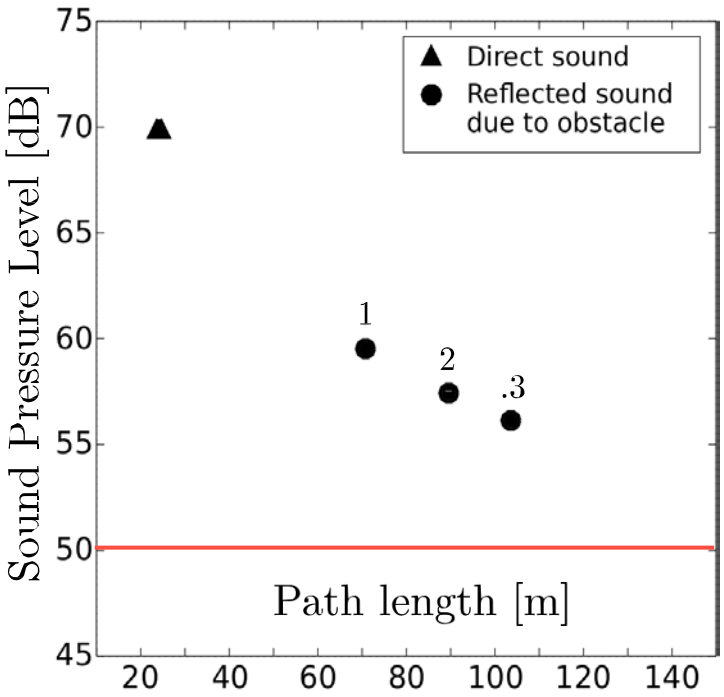


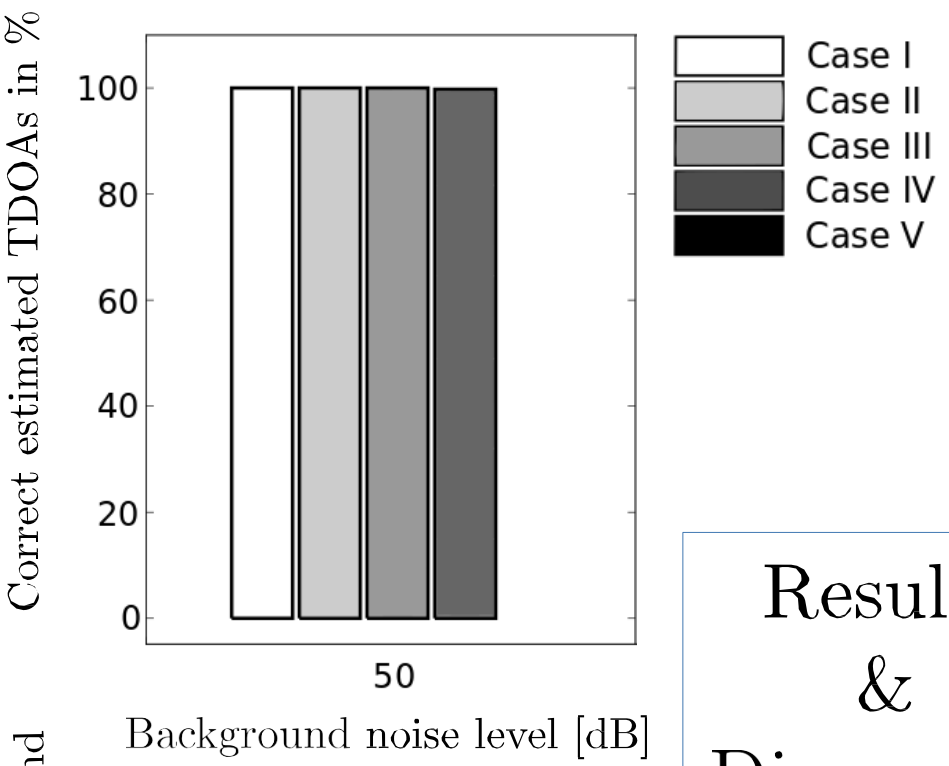




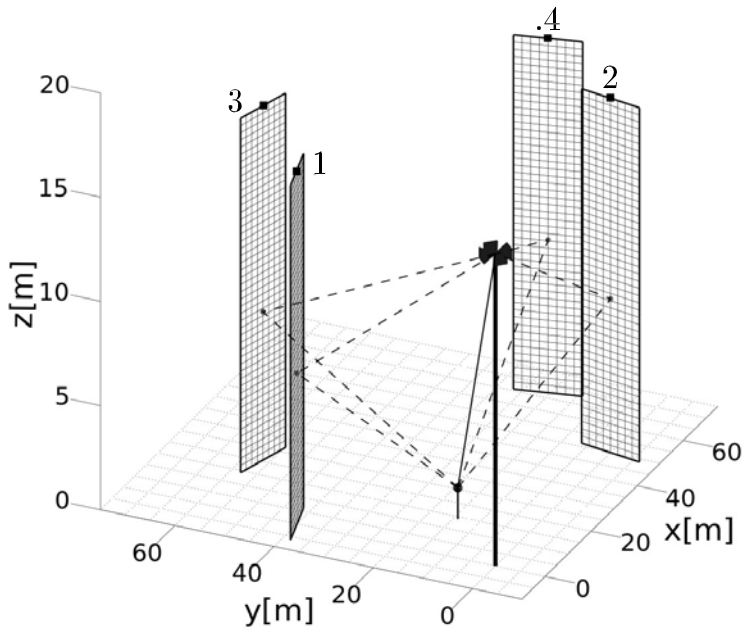
Results & Discussion

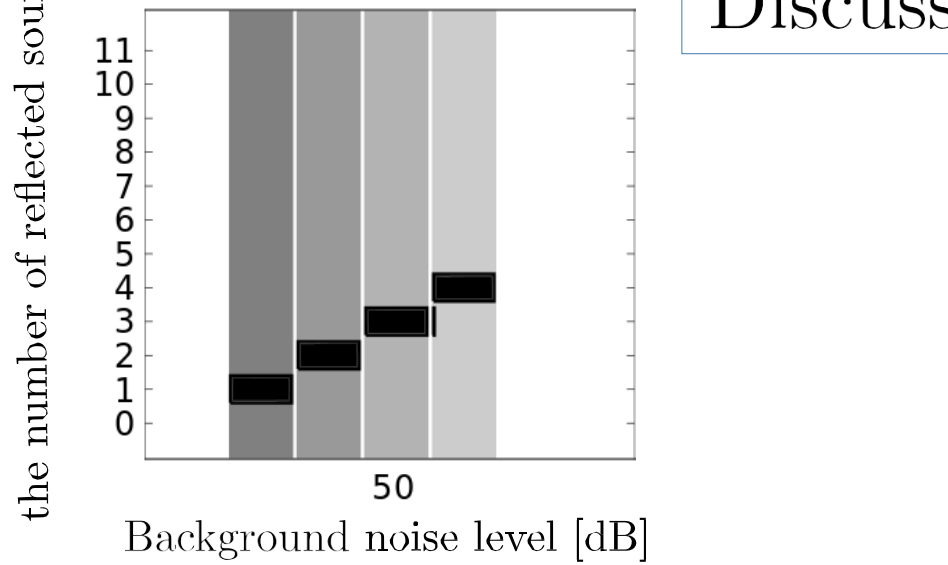


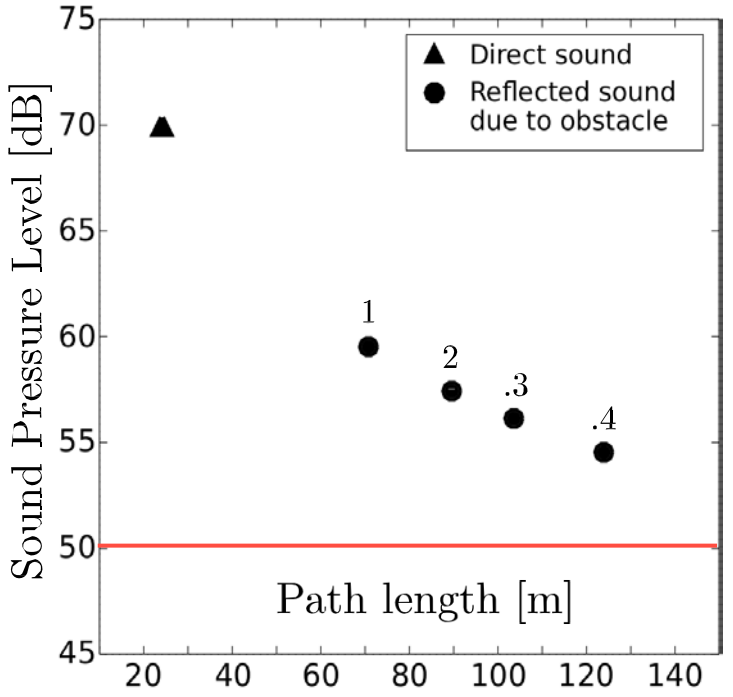


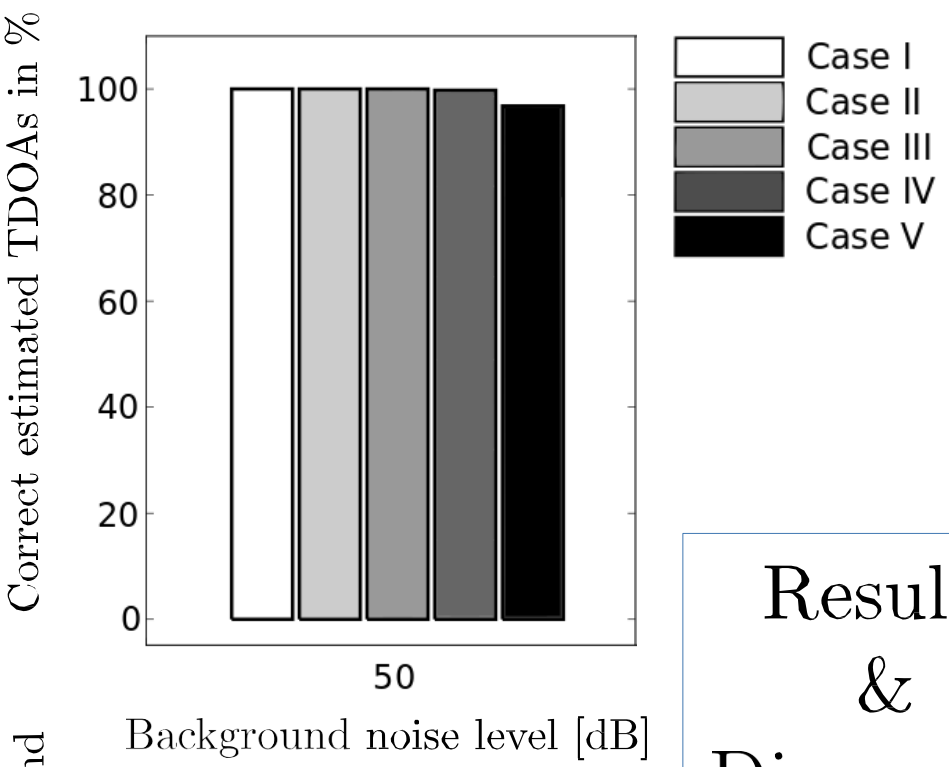


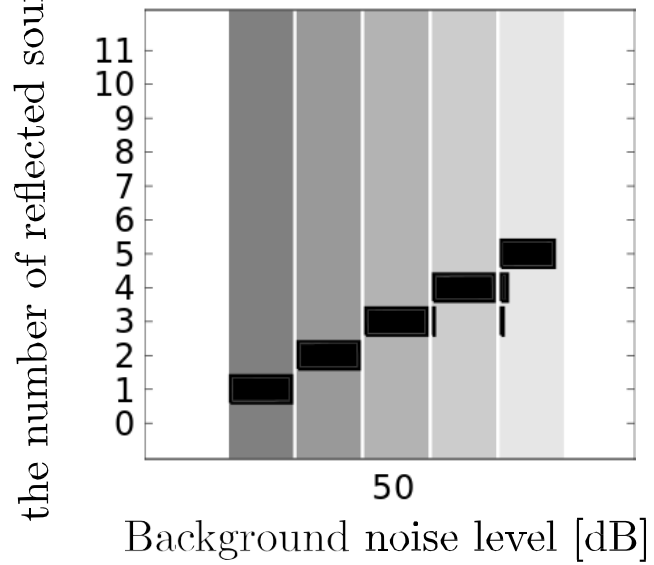
Results & Discussion



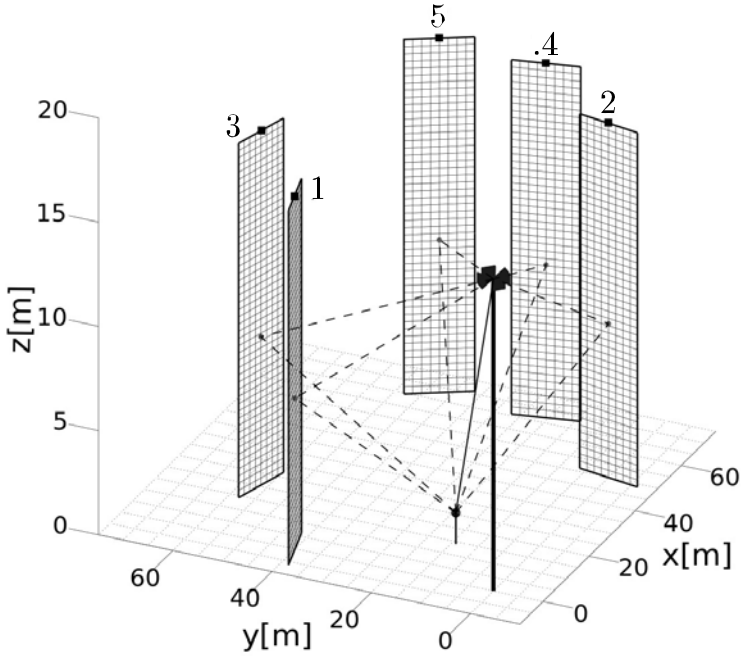


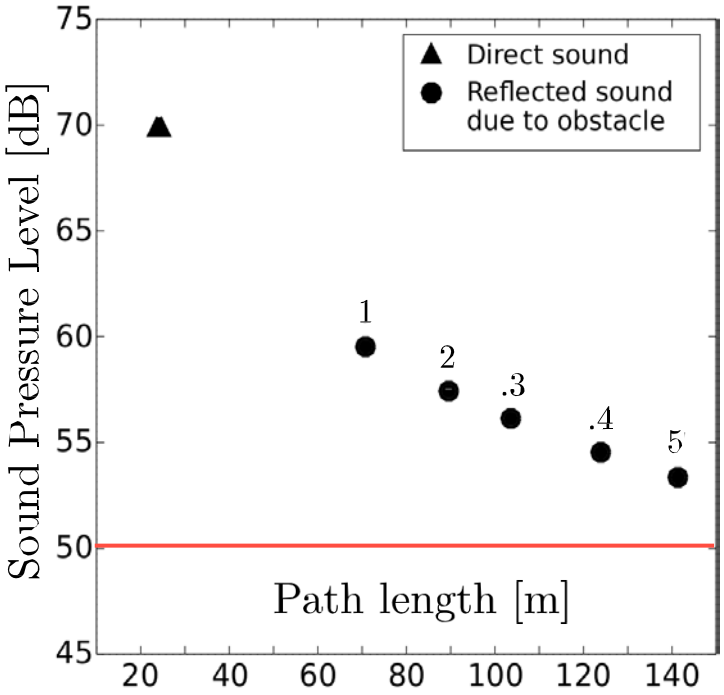


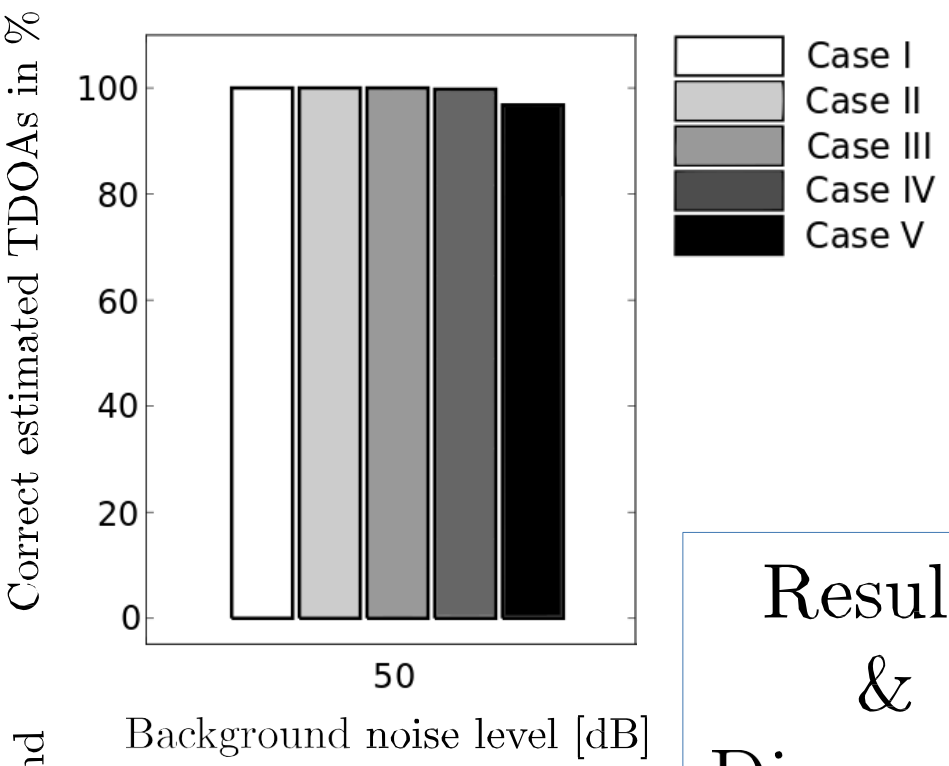


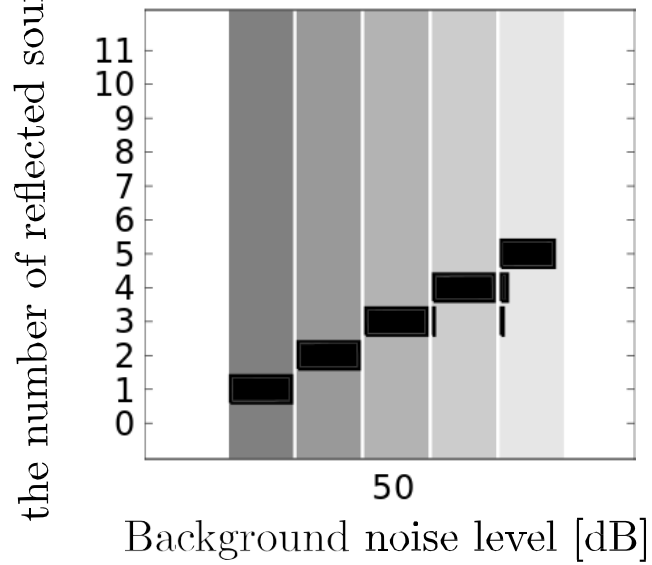


Results & Discussion

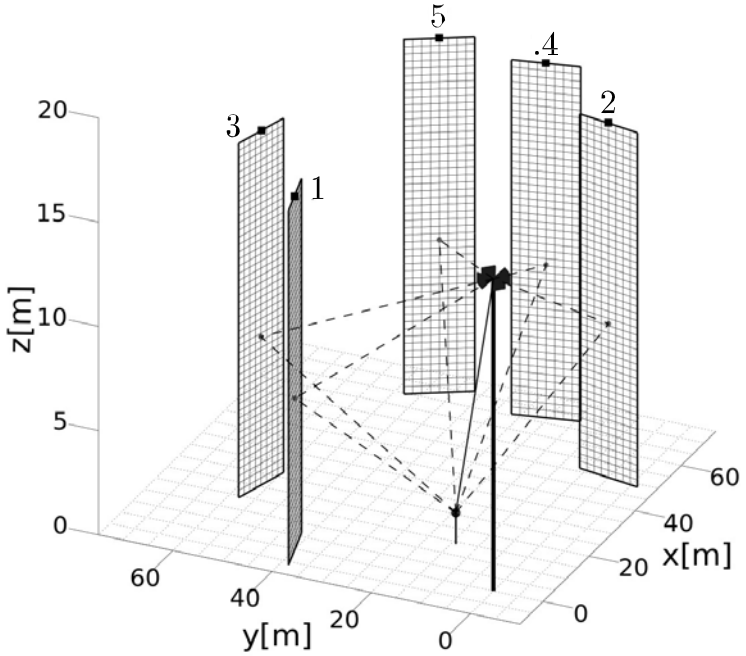


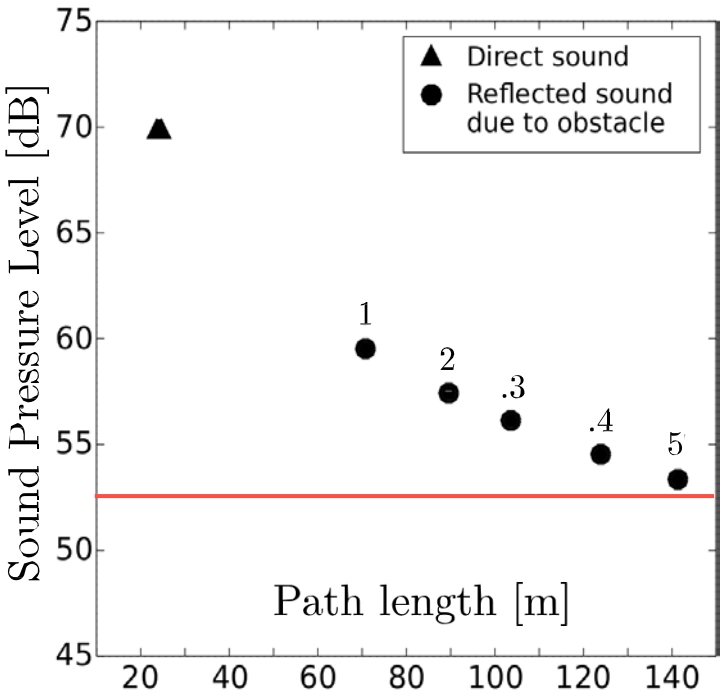


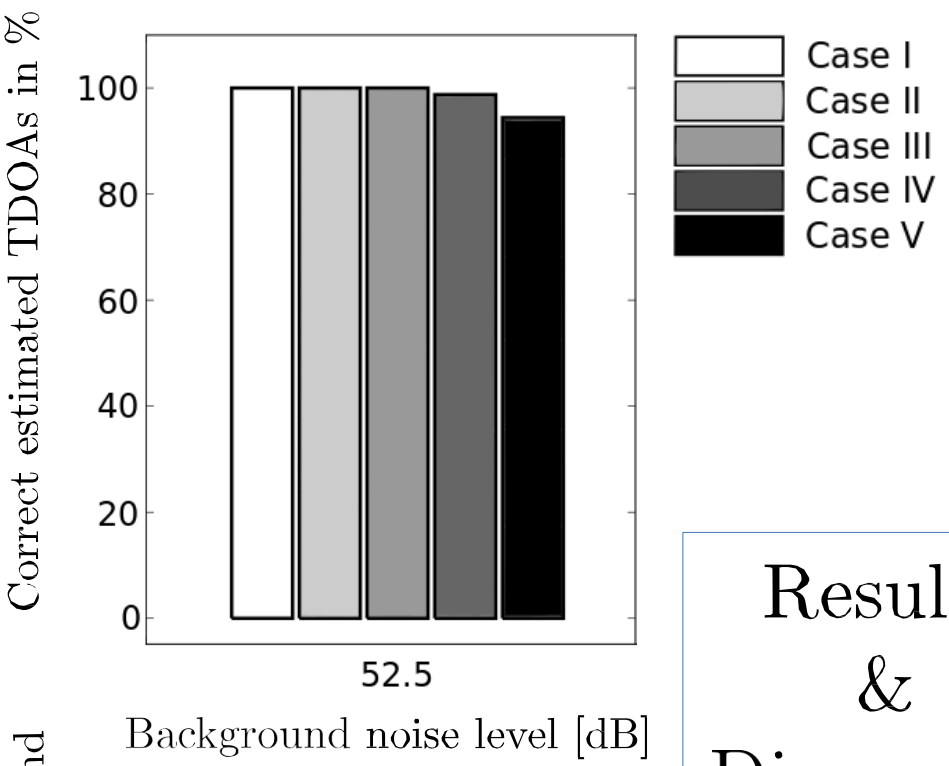


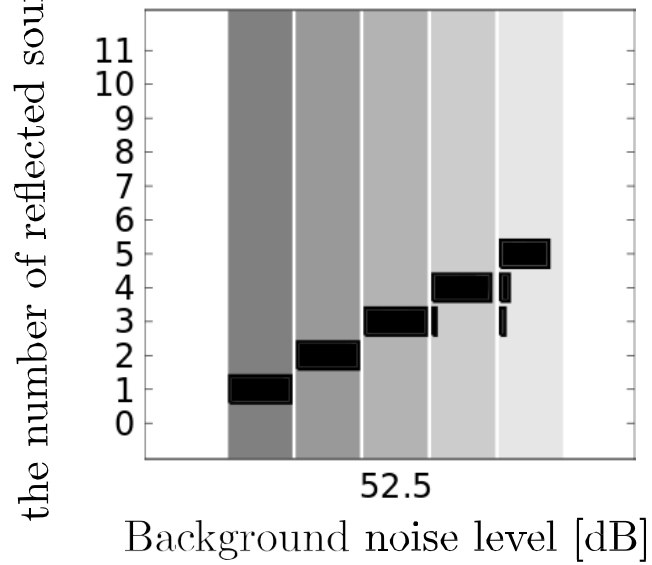


Results & Discussion

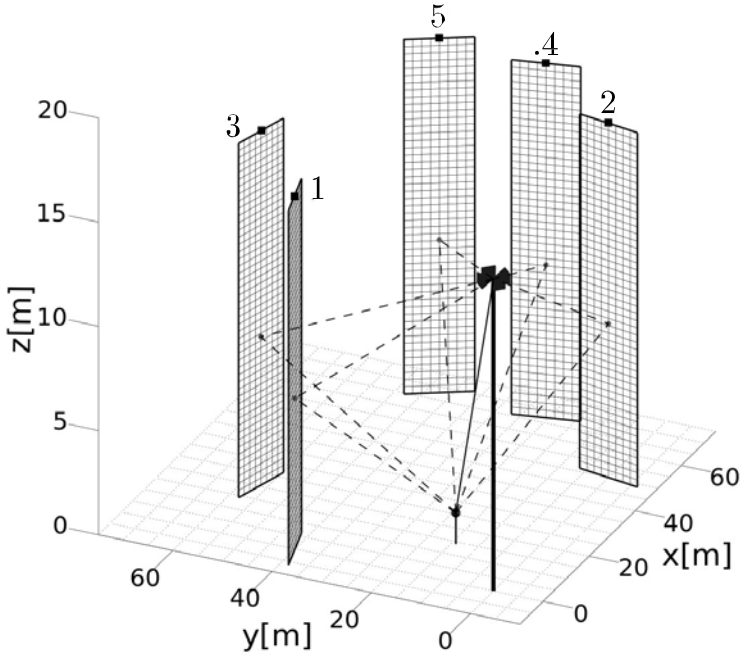


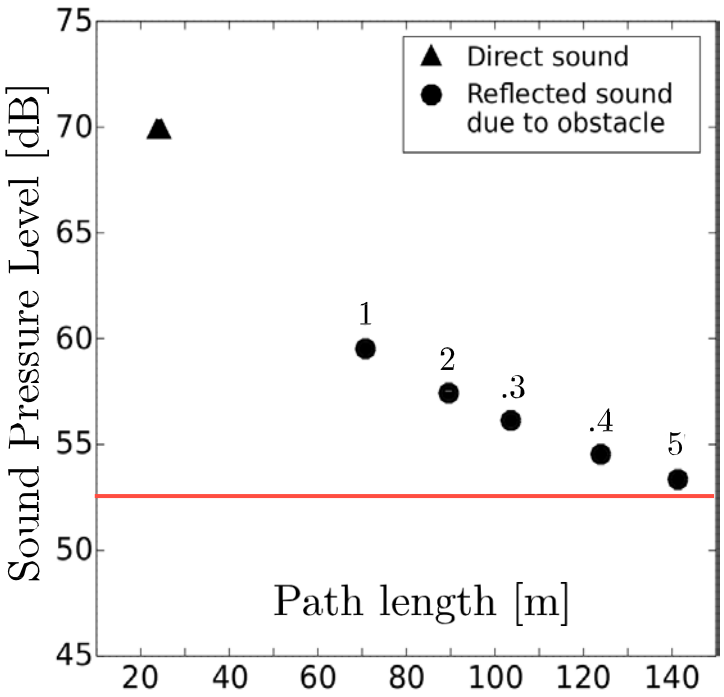


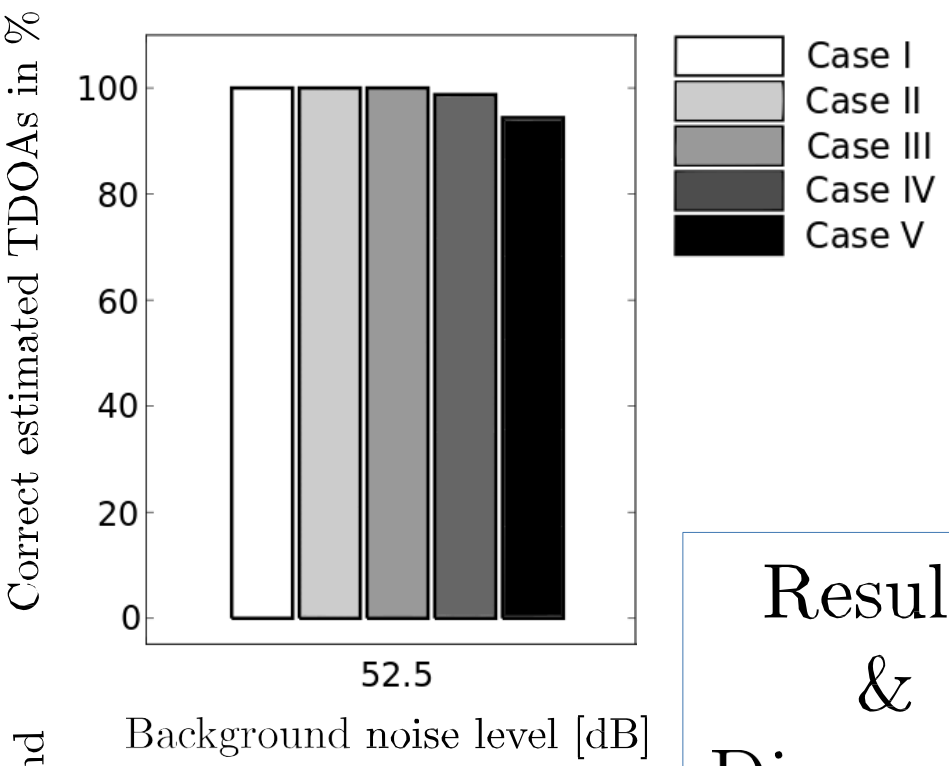


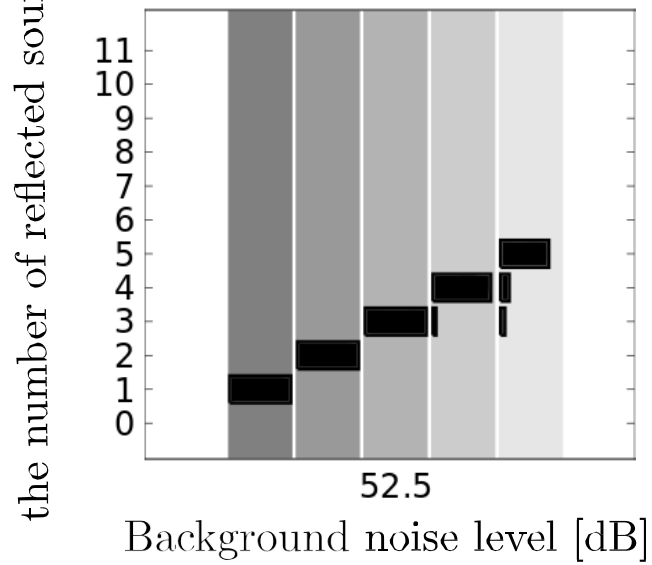


Results & Discussion

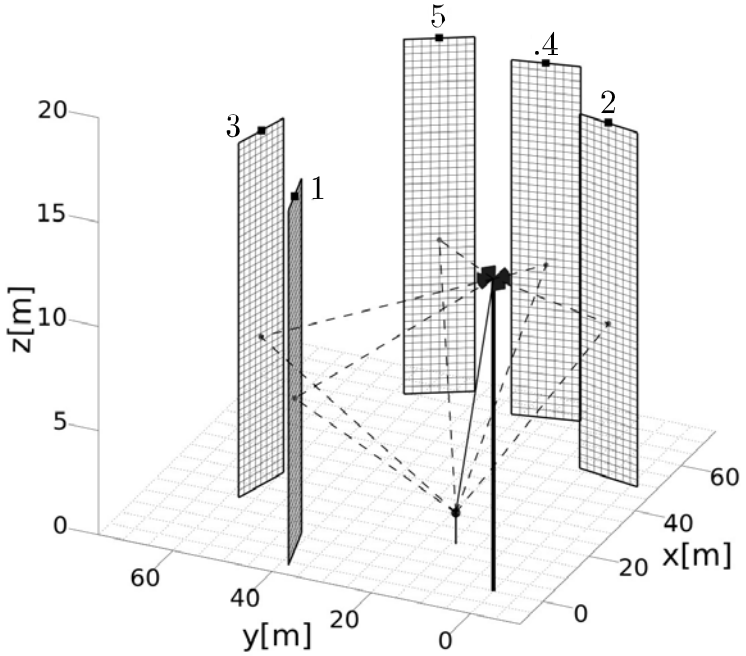


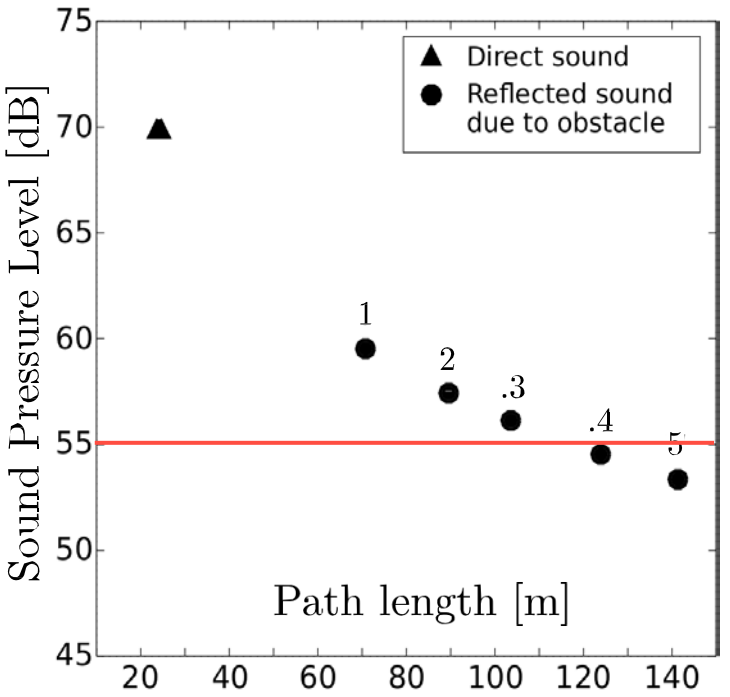


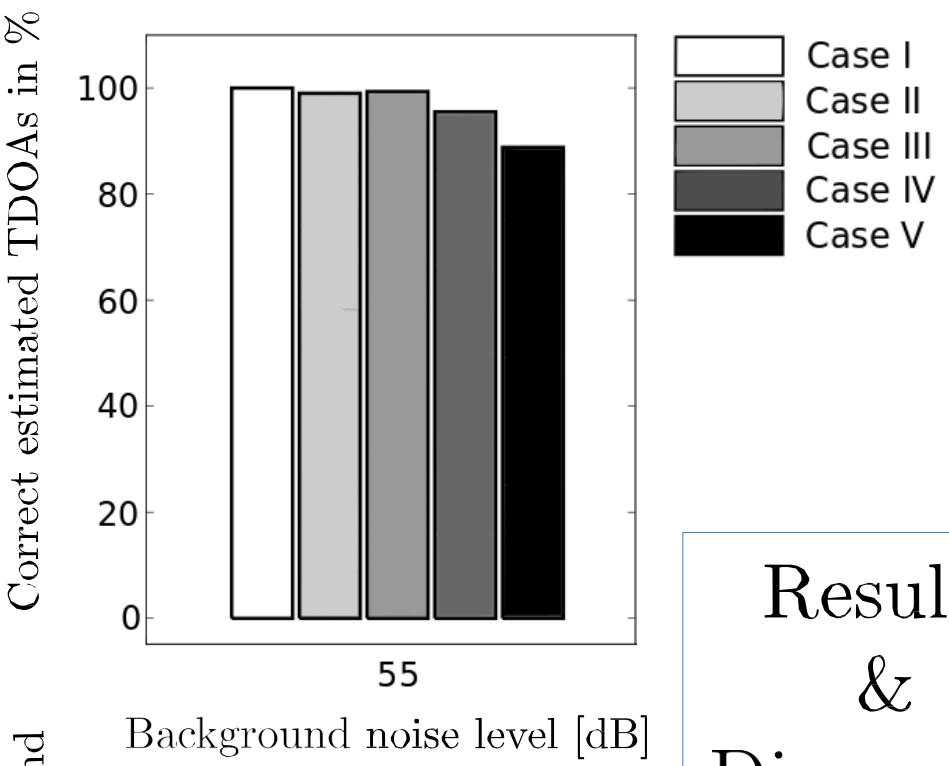


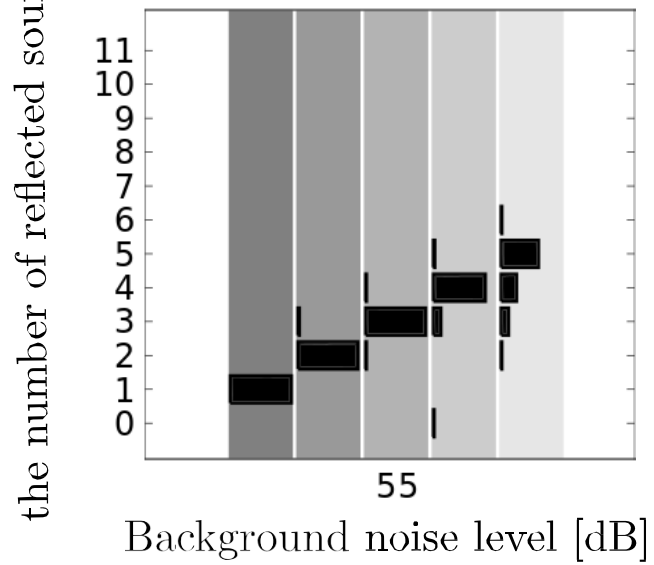


Results & Discussion

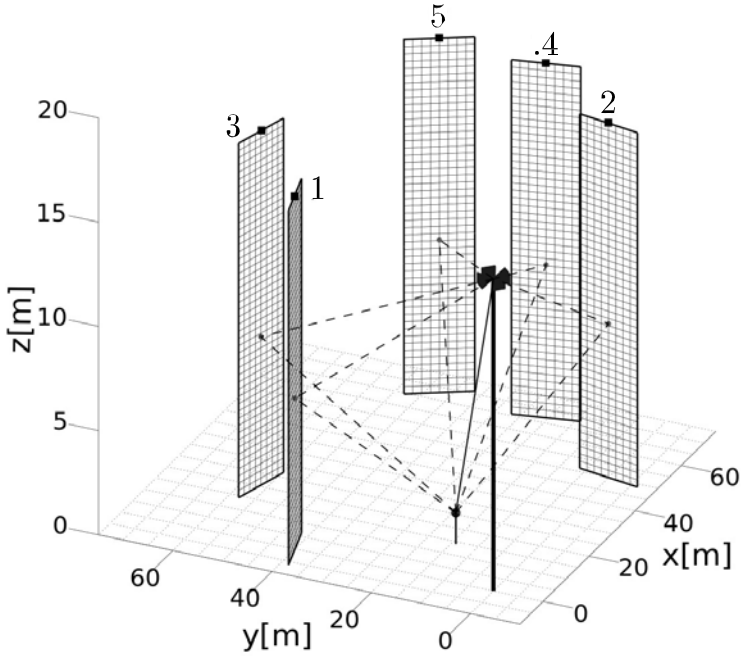


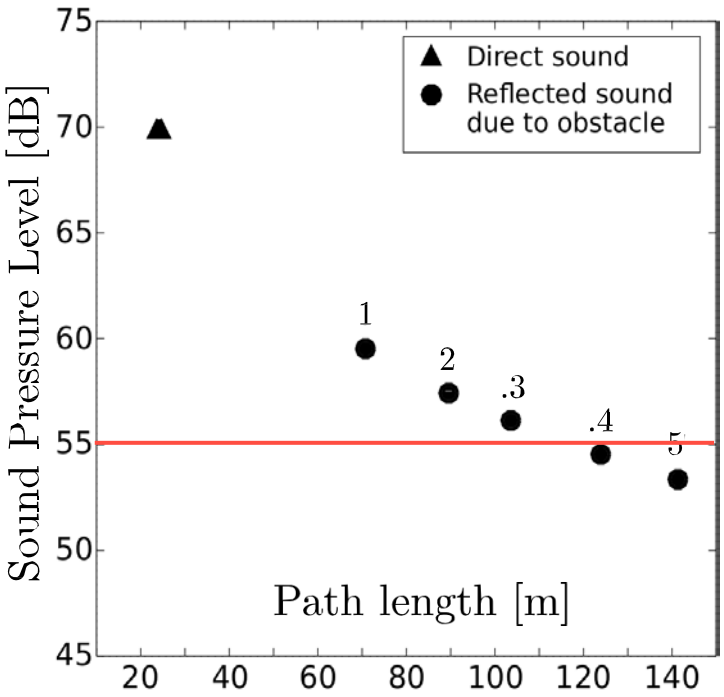


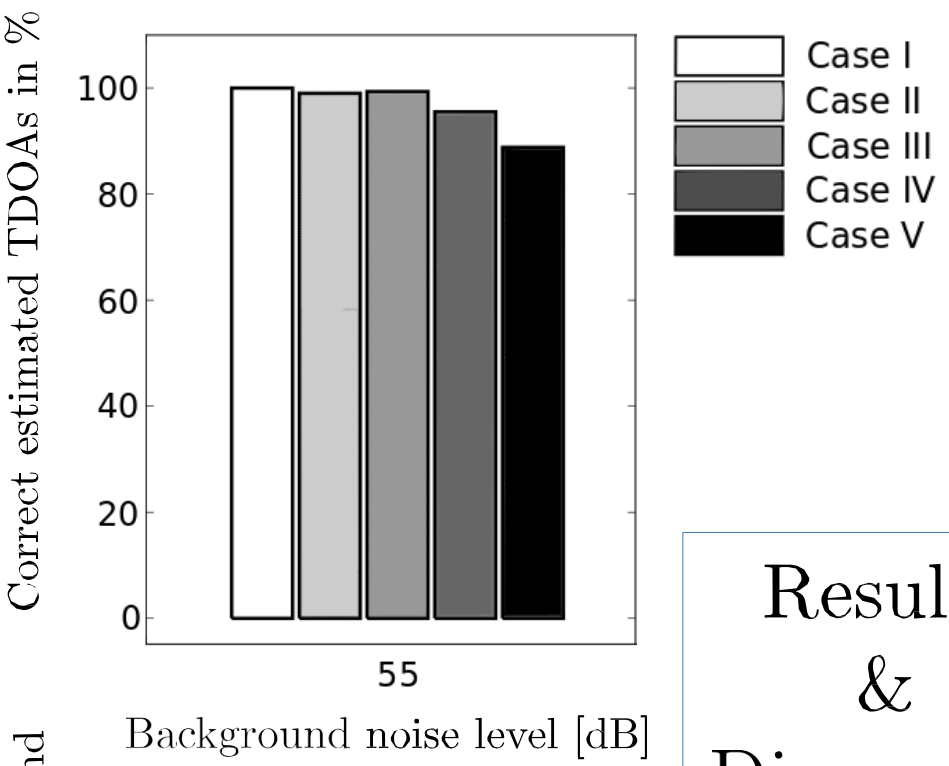


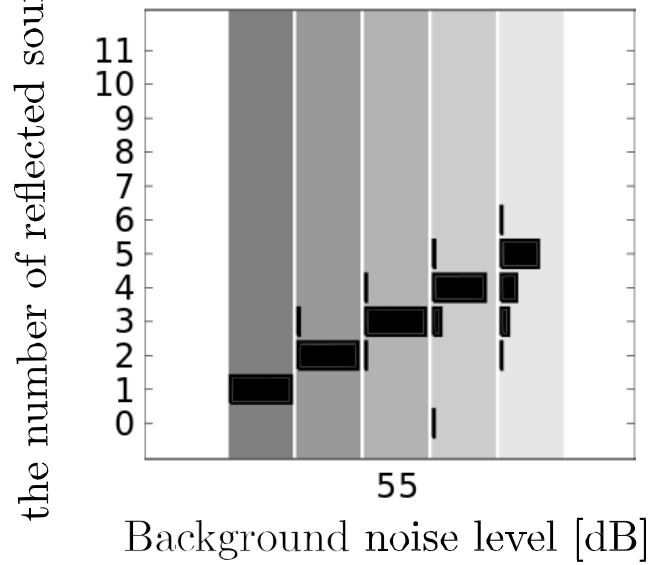


Results & Discussion

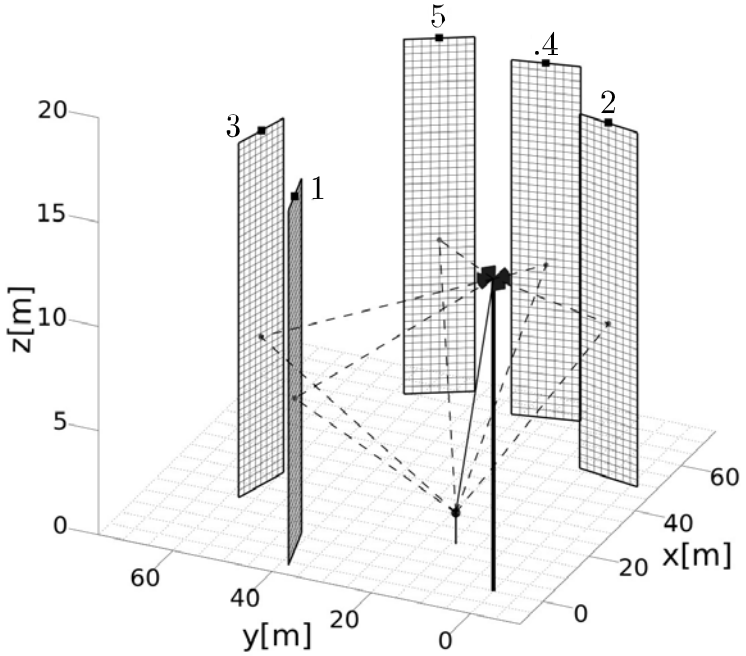


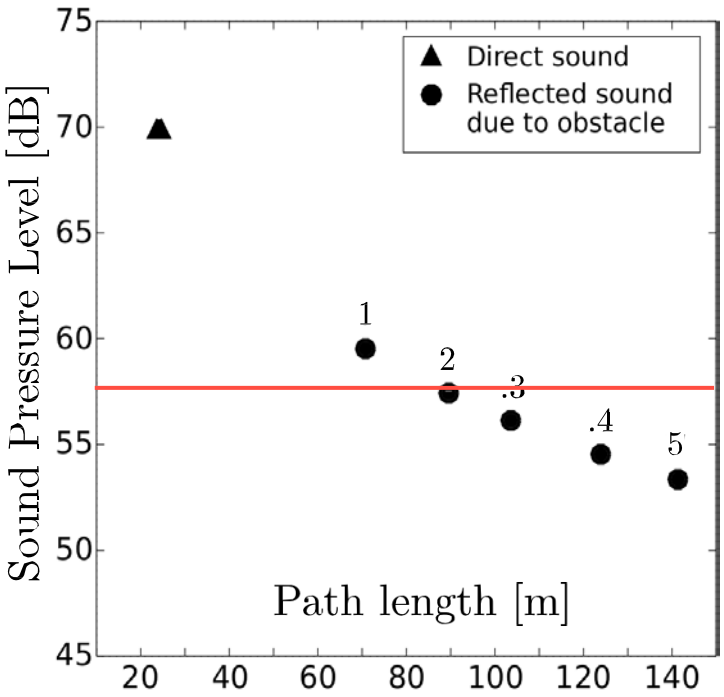


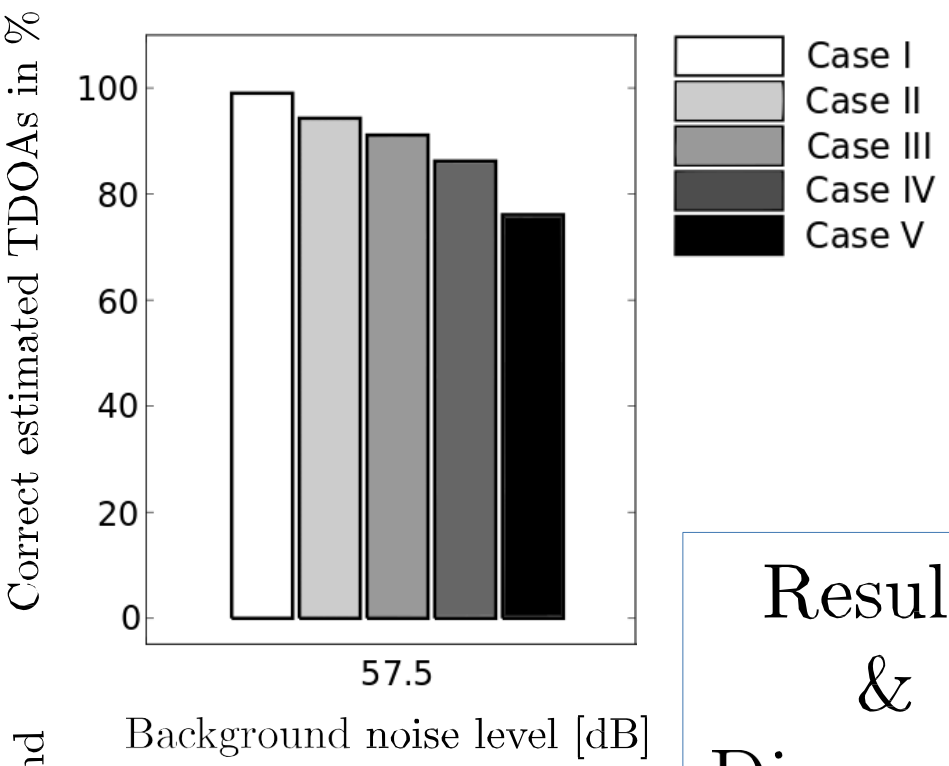


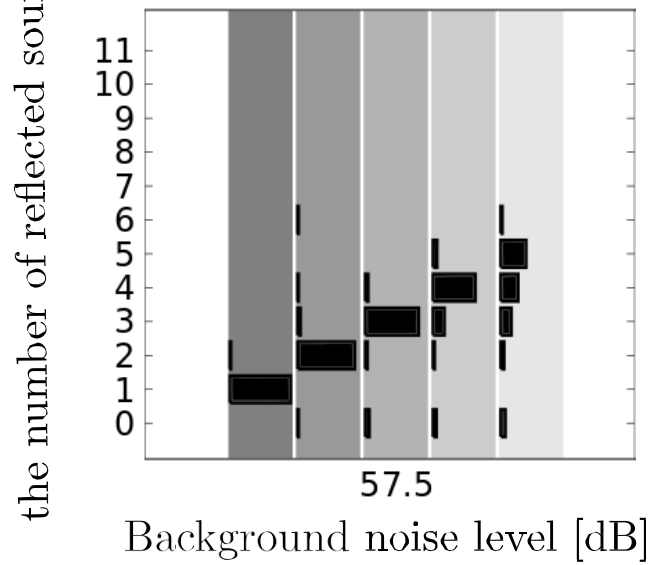


Results & Discussion

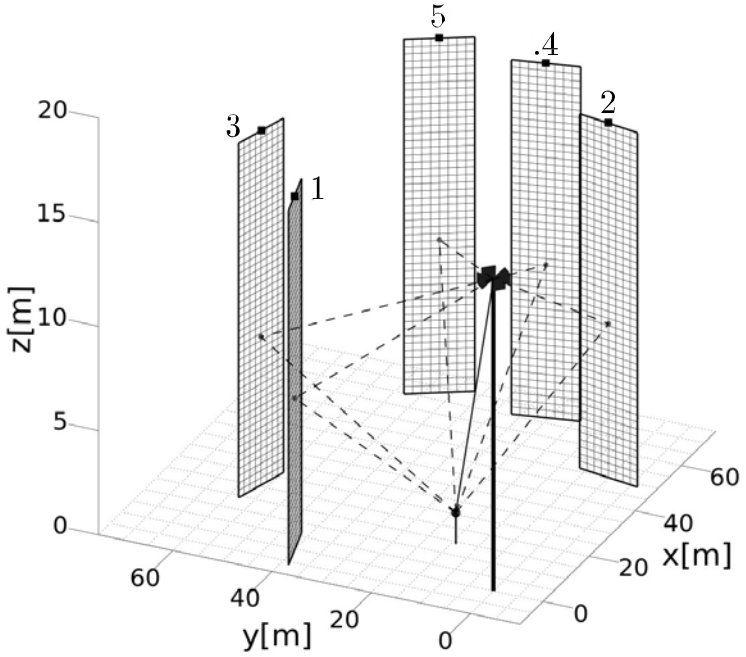


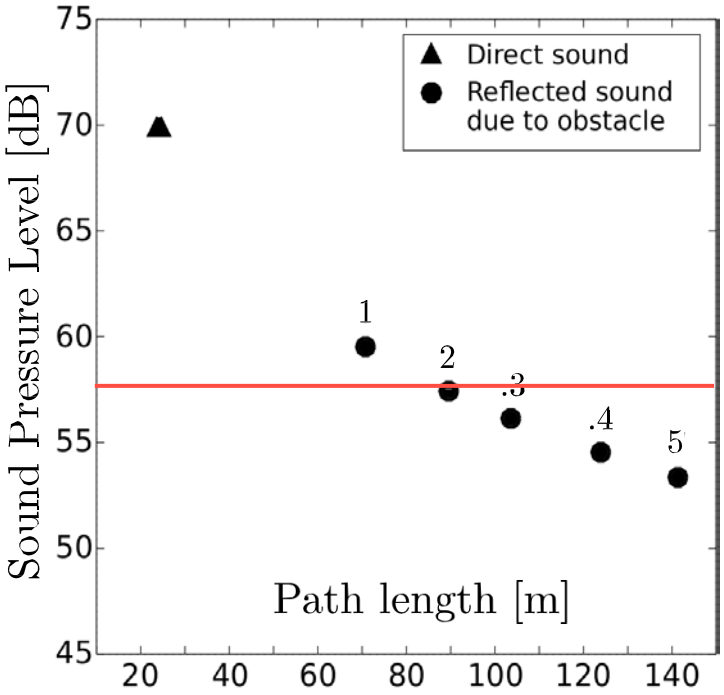


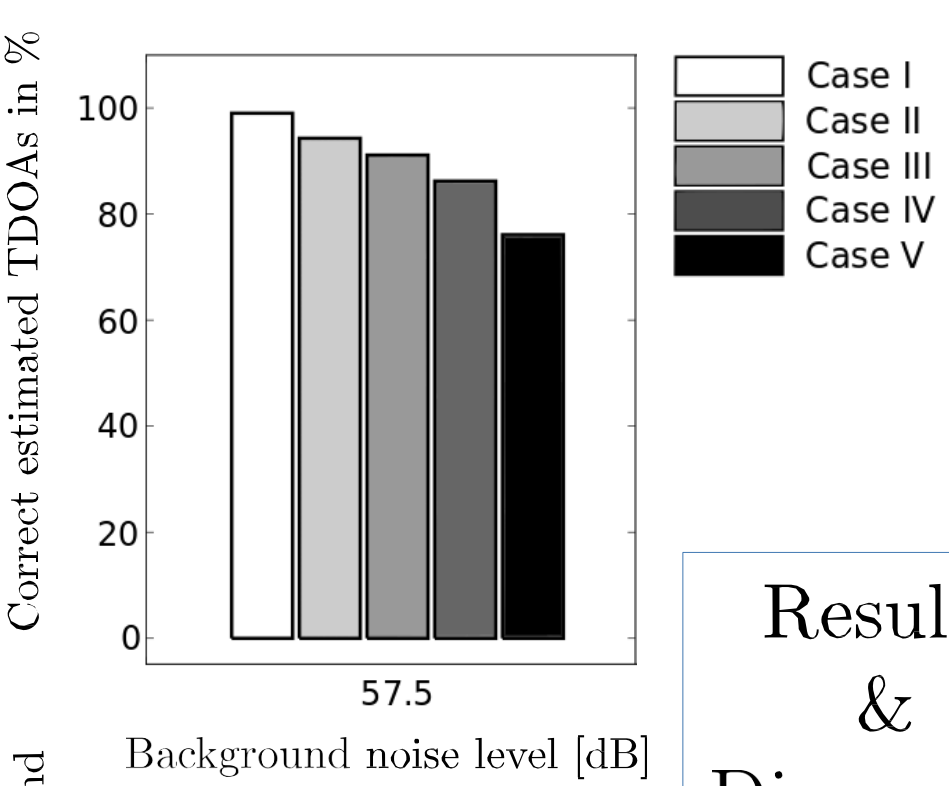


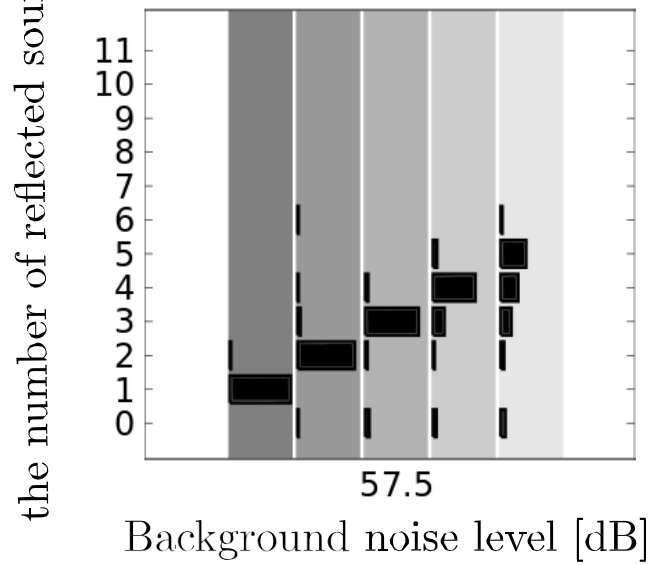


Results & Discussion

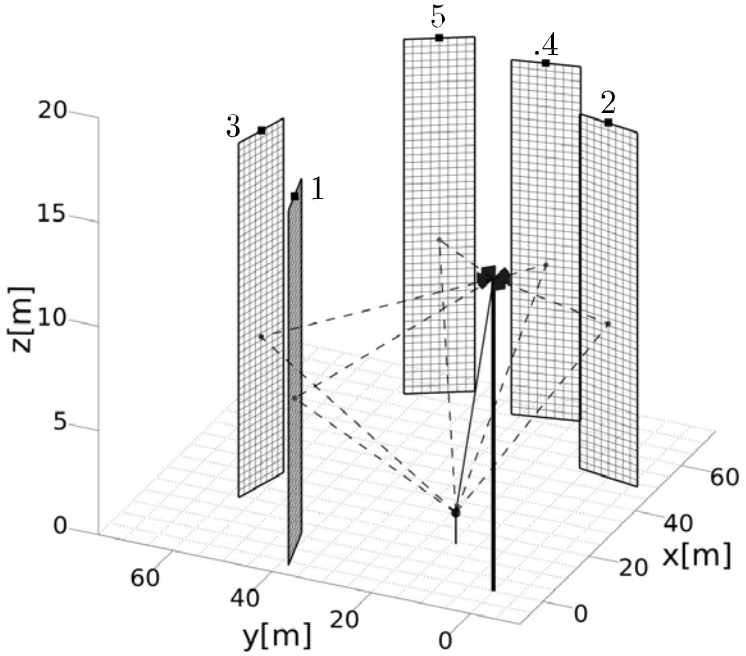


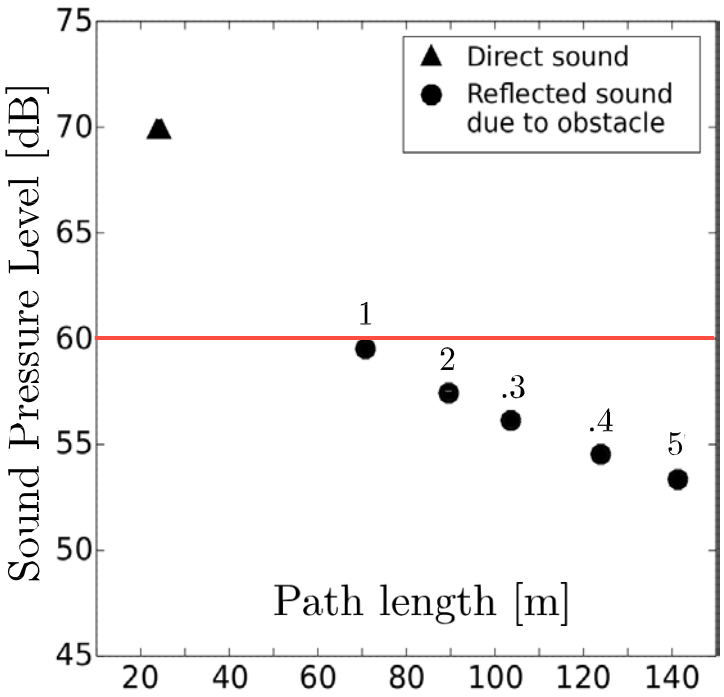


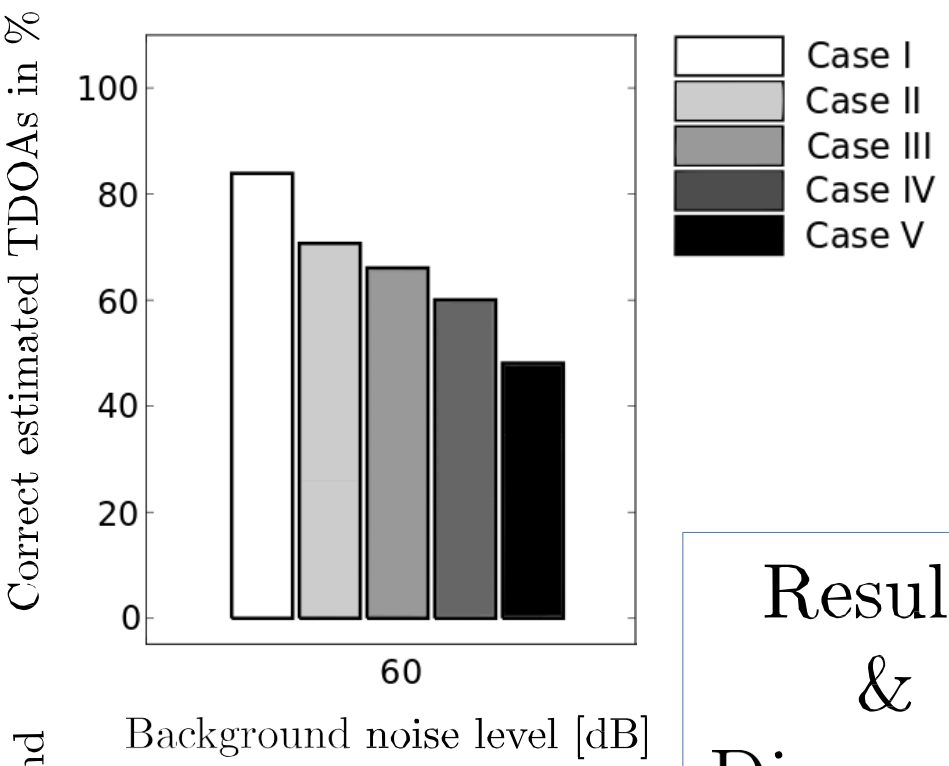


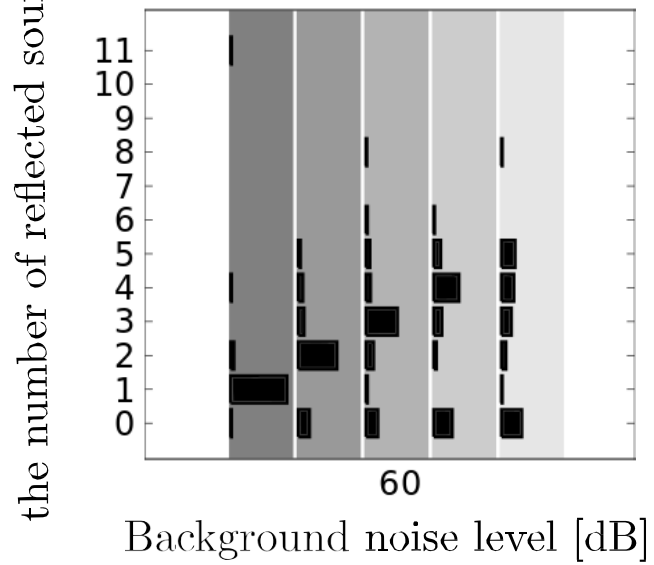


Results & Discussion

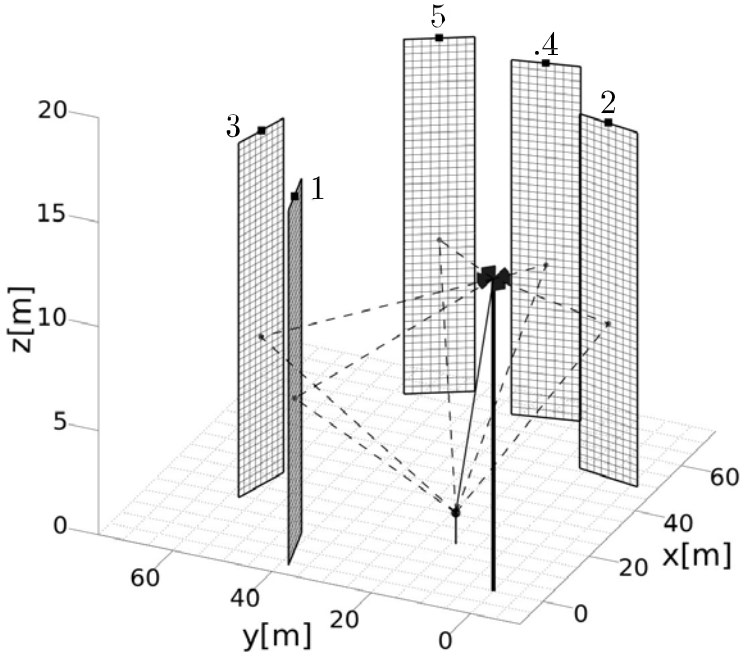


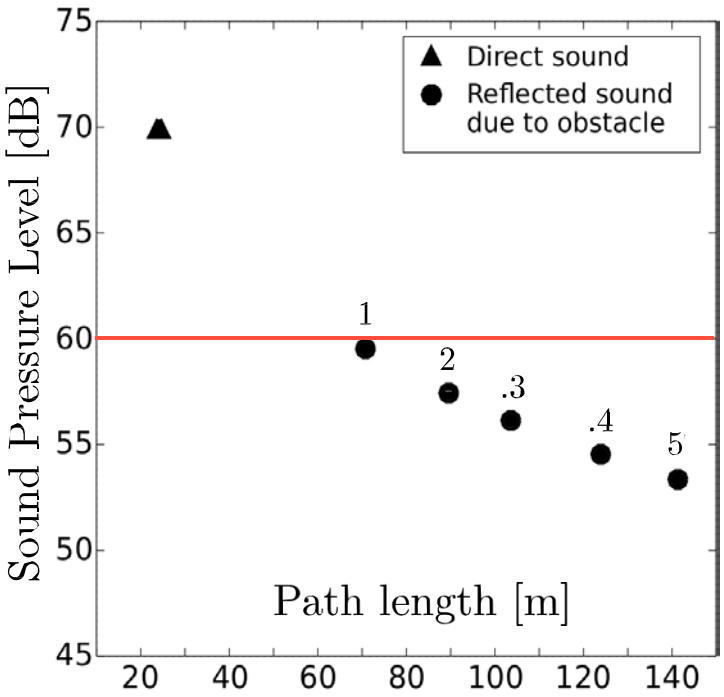


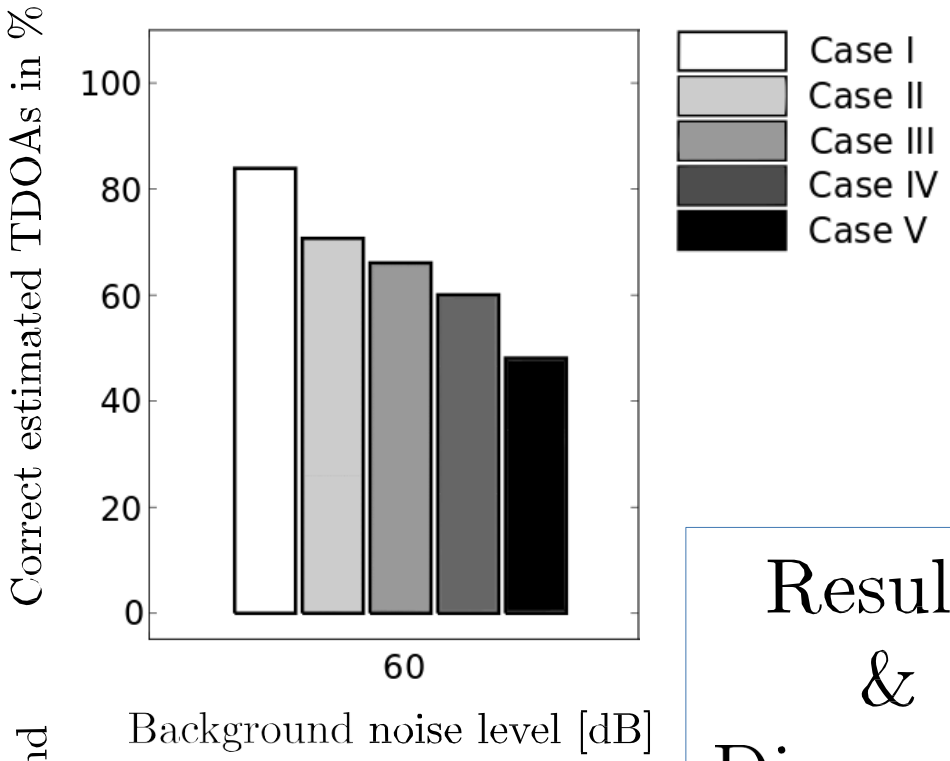


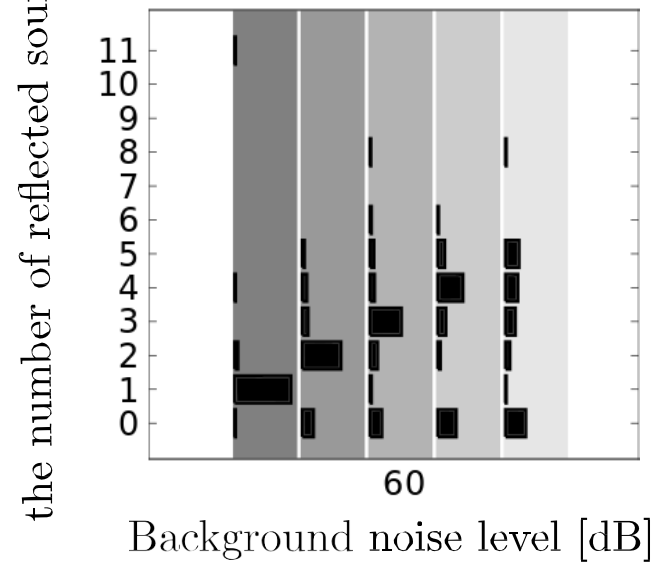


Results & Discussion

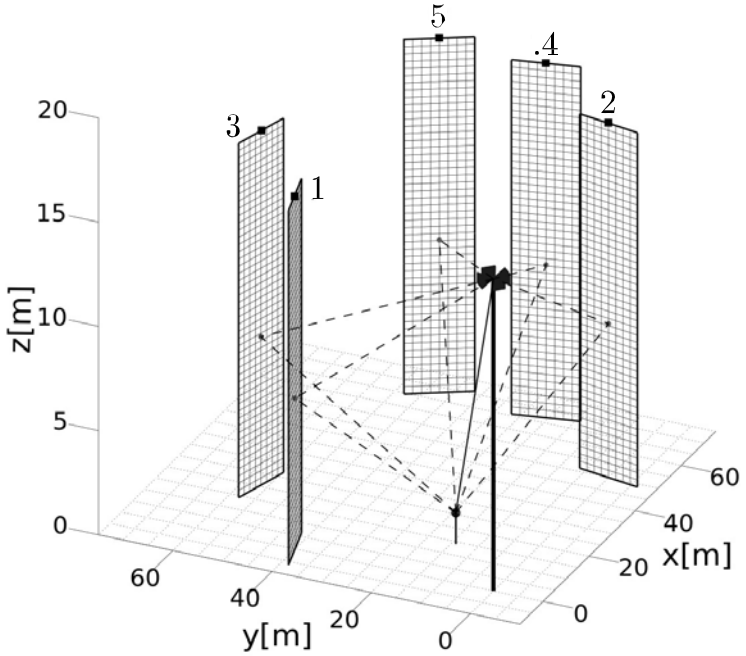


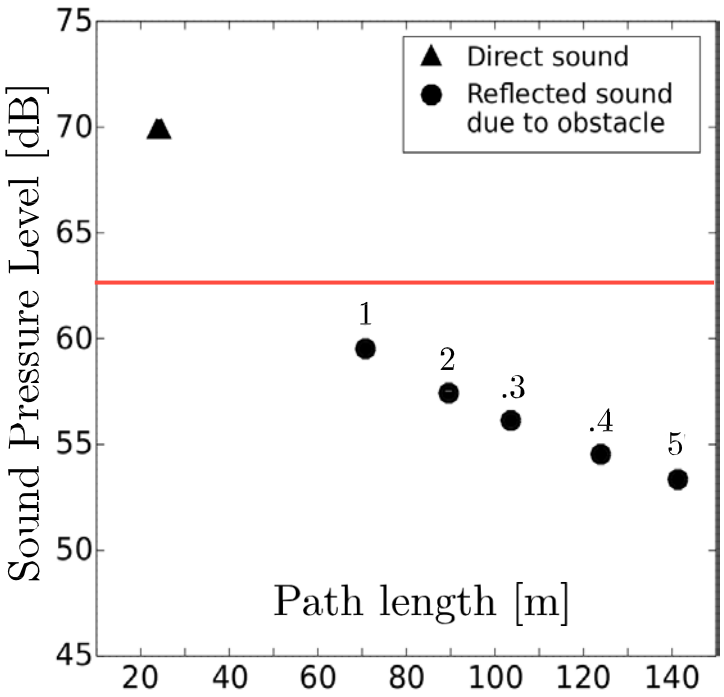


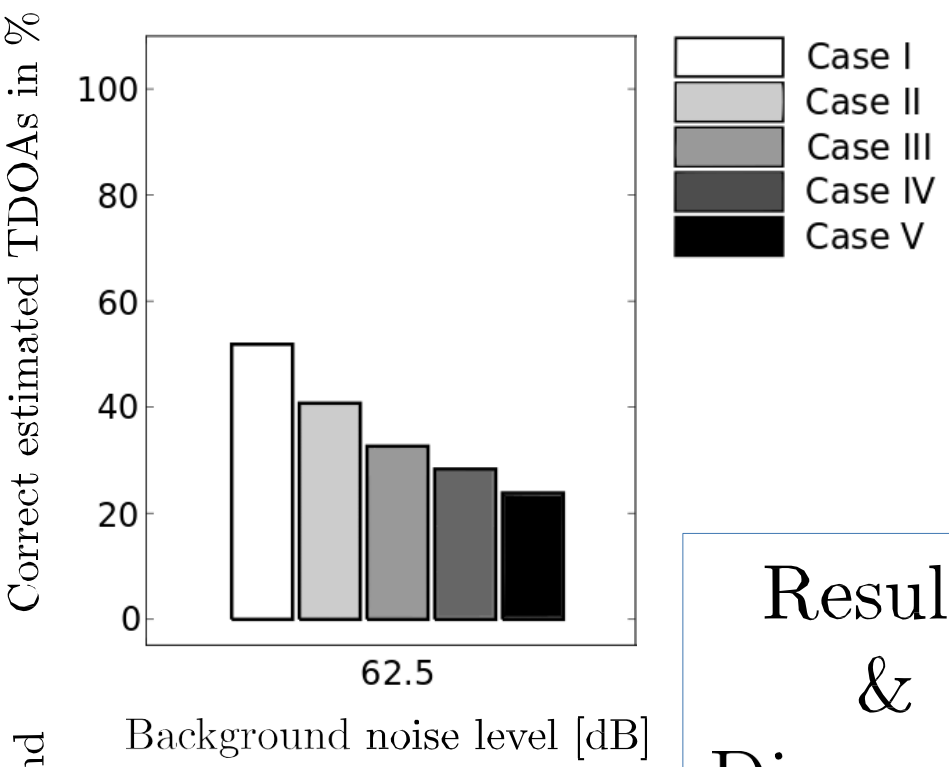


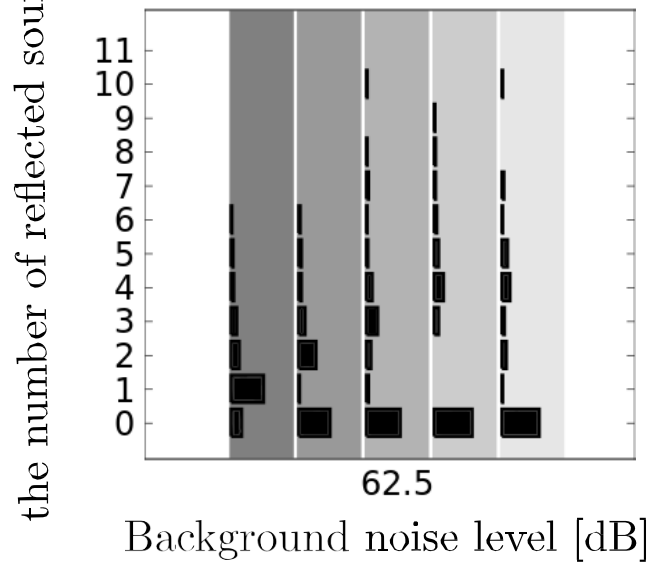


Results & Discussion

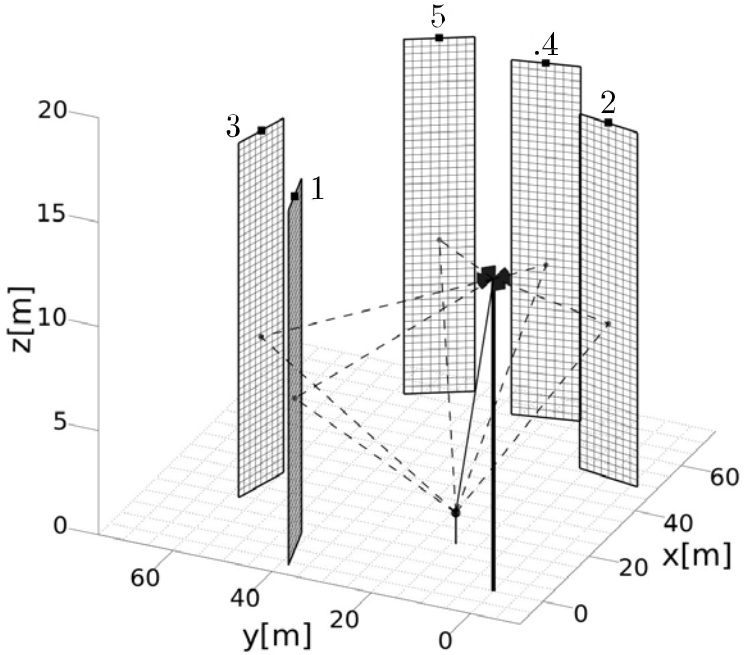


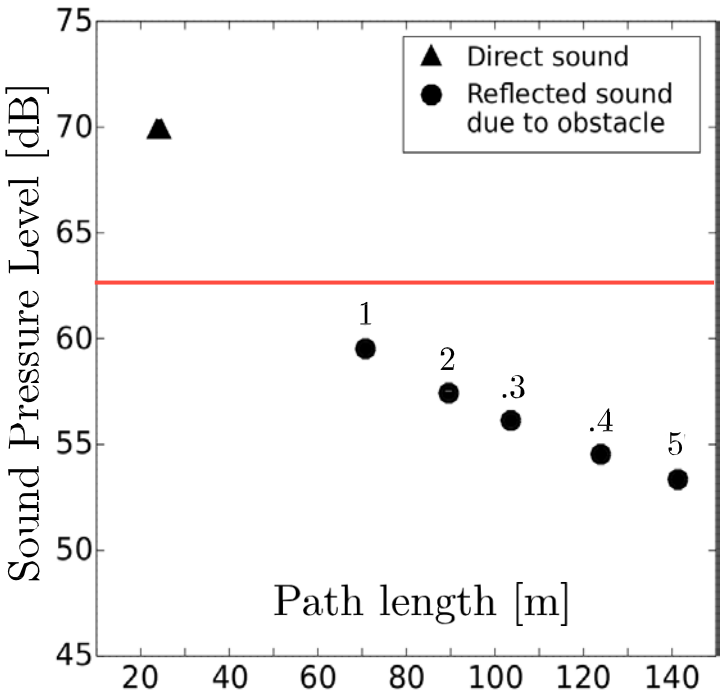


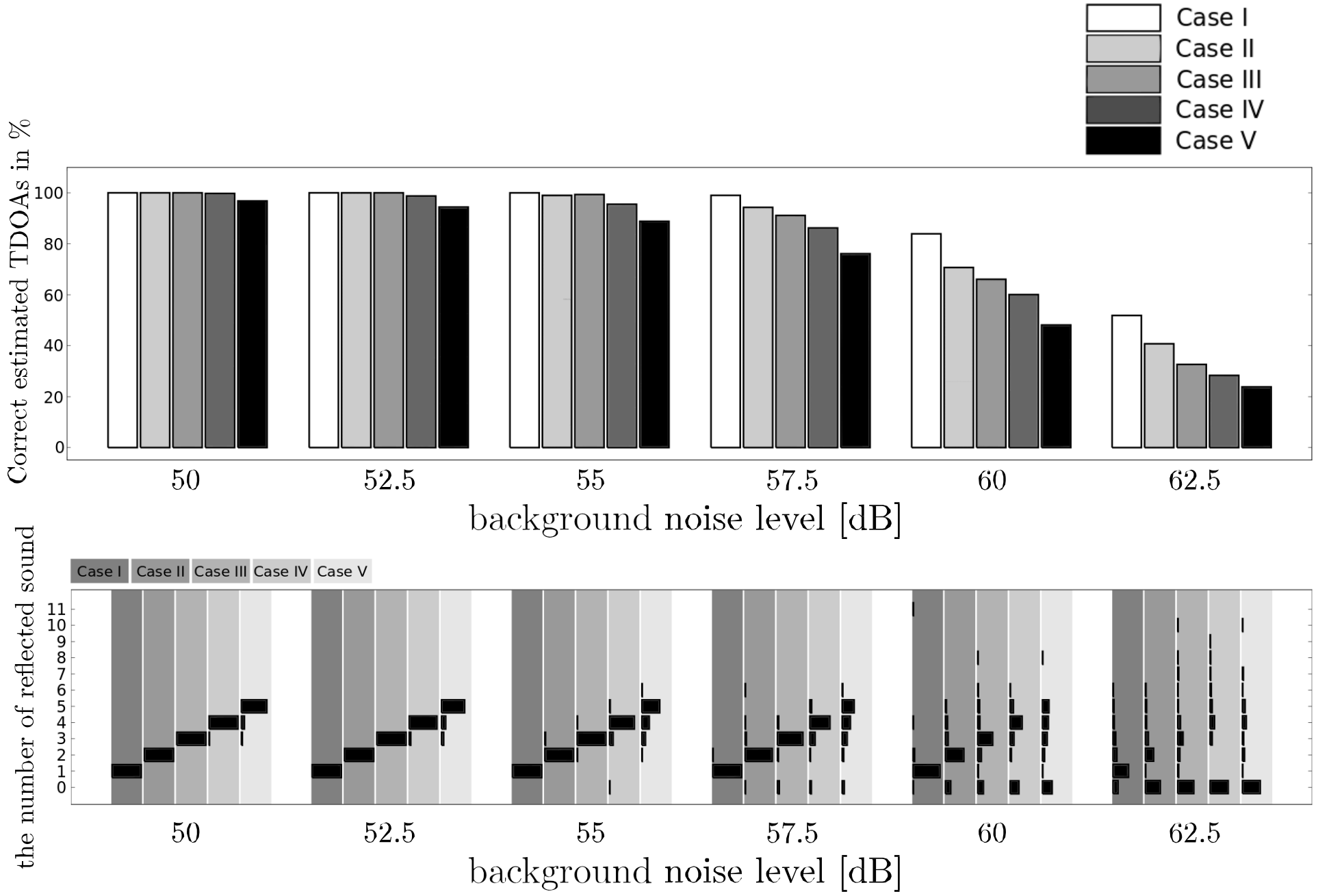




Results & Discussion






Case I
Case II
Case III
Case IV
Case V
Correct estimated TDOAs in %
100
80
60
40
20
0
50
52.5
55
57.5
60
62.5
background noise level [dB]
Case I
Case II
Case III
Case IV
Case V
the number of reflected sound
11
10
9
8
7
6
5
4
3
2
1
0
50
52.5
55
57.5
60
62.5
background noise level [dB]

Conclusions

- Intelligent public address system with a network connection is introduced.
- Since the algorithm is simple, implementation on a single board computer is easy.
- Estimation of direct and reflected sounds is proposed.

Future works:

- Experiments in a field.
- Mapping system will be developed.