Measurement of the Head Related Transfer Function using the Spark Noise

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INTRODUCTION

- Interaural Time Difference
- Interaural Level Difference
- Reverberations
- Doppler Effect
  ...

[Images of a bus, violinist, and car, with arrows pointing to each other and to a figure in a lab coat holding a clipboard.]

3D SOUND LOCALIZATION

Head Related Transfer Functions (HRTFs)

- Impulse response between the sound source and the entrance of the ear canal
- Depend on the source directions:
  - Horizontal and vertical
  - Distance

- The 3D audio systems based on the HRTFs need very large number of different HRTFs
IMPULSE RESPONSE

• MEASUREMENT EQUIPMENT
  – Loudspeaker
  – Time stretched pulse, M-sequence, Golay code

• FAR FIELD
  – Consideration of the point source

• NEAR FIELD
  – The influences by the features of the loudspeaker
DIRECTIVITY OF LOUDSPEAKER

Azimuth [deg]

Frequency [kHz]

Magnitude [dB]

0
-10
-20
-30
-40
-50
-60

0
10
20
15
10
5
0
-50
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
-20
-30
-40
-50
PURPOSE

• HRTF measurement in the near field
  – Specification of the equipment
    • Point source
    • No or less directivity
    • SNR 40 dB

EXPERIMENT

• HRTF measurement with the spark between two electrodes
ELECTRODE

• Needle electrode
  – Copper
  – Needle size  0.2 mm
  – Gap        2 mm

• Sphere electrode
  – Copper-chromium alloys
  – Sphere diameter  7 mm
  – Gap           2 mm
FREQUENCY RESPONSE

Magnitude [dB] vs Frequency [kHz]

- Blue line represents Needle
- Red line represents Sphere

Frequency values range from 0 to 24 kHz
Magnitudes range from -80 dB to 0 dB
### HRTF MEASUREMENT

<table>
<thead>
<tr>
<th>Sound source</th>
<th>Needle Electrode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loudspeaker (TSP signal)</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>150, 200, 250, 300 mm</td>
</tr>
<tr>
<td>Azimuth</td>
<td>0, 30, …, 330 deg</td>
</tr>
<tr>
<td>Head and torso simulator</td>
<td>B&amp;K 4128</td>
</tr>
</tbody>
</table>
OBJECTIVE MEASURE

Spectral Distortion

\[
SD = \sqrt{\frac{1}{257} \sum_{i=0}^{256} \left( 20 \log\left( \frac{|H_s(f_i)|}{|H_t(f_i)|} \right) \right)^2} \quad [\text{dB}]
\]

\[
f_0 = 0.0 \quad [\text{kHz}]
\]

\[
f_{256} = 24.0 \quad [\text{kHz}]
\]

\(H_s(f_i)\)  Magnitude response of the HRTF with the spark

\(H_t(f_i)\)  Magnitude response of the HRTF with the TSP
The both HRTFs differ in close to the head.
SUBJECTIVE TESTS

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Whisper ( Male, 2.5 s )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Piano ( A5 (880 Hz), 3.2 s )</td>
</tr>
<tr>
<td>HRTF</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>150 mm</td>
</tr>
<tr>
<td>Azimuth</td>
<td>0, 30, …, 330 deg</td>
</tr>
<tr>
<td>Subject</td>
<td>5 Subjects</td>
</tr>
</tbody>
</table>
RESULTS ( Whisper )

SPARK NOISE
( 45.3 % Correct )

TSP (Loudspeaker)
( 36.7 % Correct )
RESULTS (Piano)

SPARK NOISE
(44.7% Correct)

TSP
(38.1% Correct)
CONCLUSIONS

• Investigation of the HRTF measurement with the spark noise
• The HRTFs with the spark are effective in the near field

Future Works

• Improvement of the electrode
• Measurement at many directions and distances
HRTF DATA

URL

http://www.ciair.coe.nagoya-u.ac.jp/db/

Contents

• HRTFs used in this experiment
  – Distance: 200, 300 mm
  – Azimuth: 0, 30, …, 330 deg