CCAUV/17-43

Realization of acoustic primary standards for airborne ultrasound and applications

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Introduction

- Application of airborne ultrasound
  - Consumers use; object-detection sensor, pest extermination etc.
  - Industrial equipment; liquid-level meter etc.
  - Other instruments generating airborne ultrasound unintentionally; PC display etc.

Is airborne ultrasound safe?

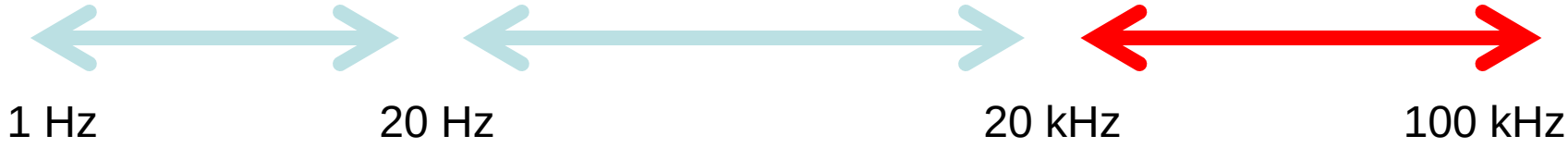
- Exposure to very high sound pressure level can be harmful to human.
  - dizziness, nauzea

- IRPA (International Radiation Protection Association) → a guideline for allowable sound pressure level of airborne ultrasound

  25-100 kHz, 110 dB at work

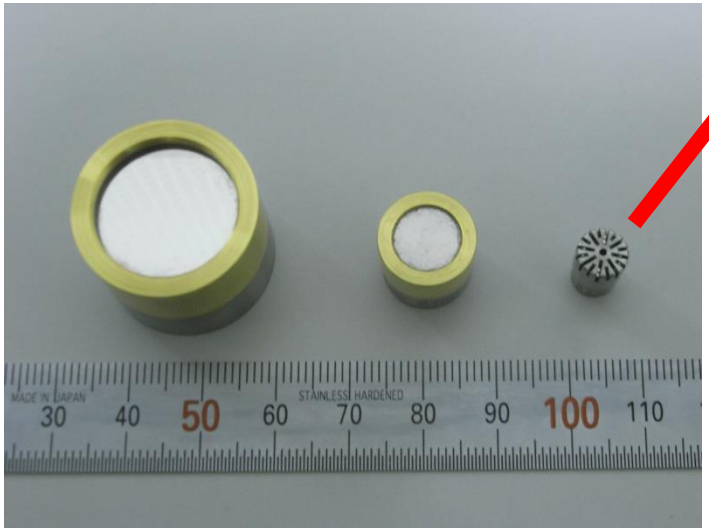
- No acoustic primary standards for ensuring reliable measurement of airborne ultrasound

Acoustic primary standards at NMIJ



Laser pistonphone Pressure reciprocity Free-field reciprocity

LS1P LS2P WS3

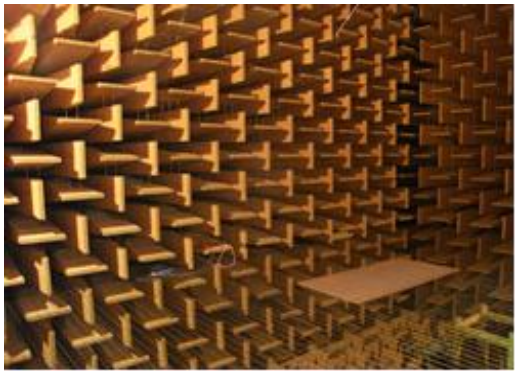


Determination of absolute sensitivity level

- Free-field reciprocity calibration (IEC 61094-3)
- Pressure reciprocity calibration (IEC 61094-2)

Free-field environment at NMIJ

- Large anechoic room
  (9.5 m x 8.0 m x 7.2m)
  – Reciprocity for LS microphones
  – SLM and WS microphones by comparison



- Compact anechoic chamber
  (1.8 m cube)
  – Reciprocity for WS3 microphones

Reciprocity of condenser microphone

Acoustic port

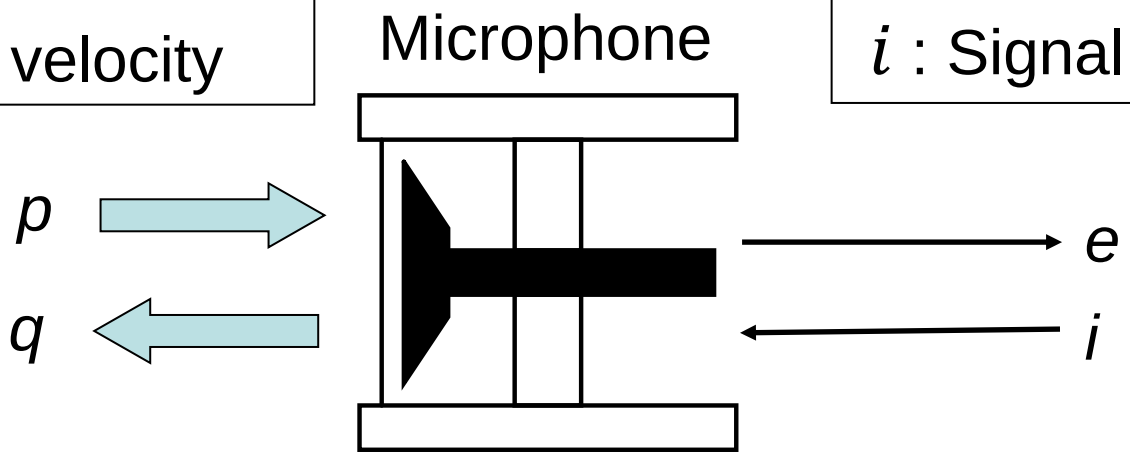
p: Sound pressure

q: Volume velocity

Electric port

e: Signal voltage

i : Signal current

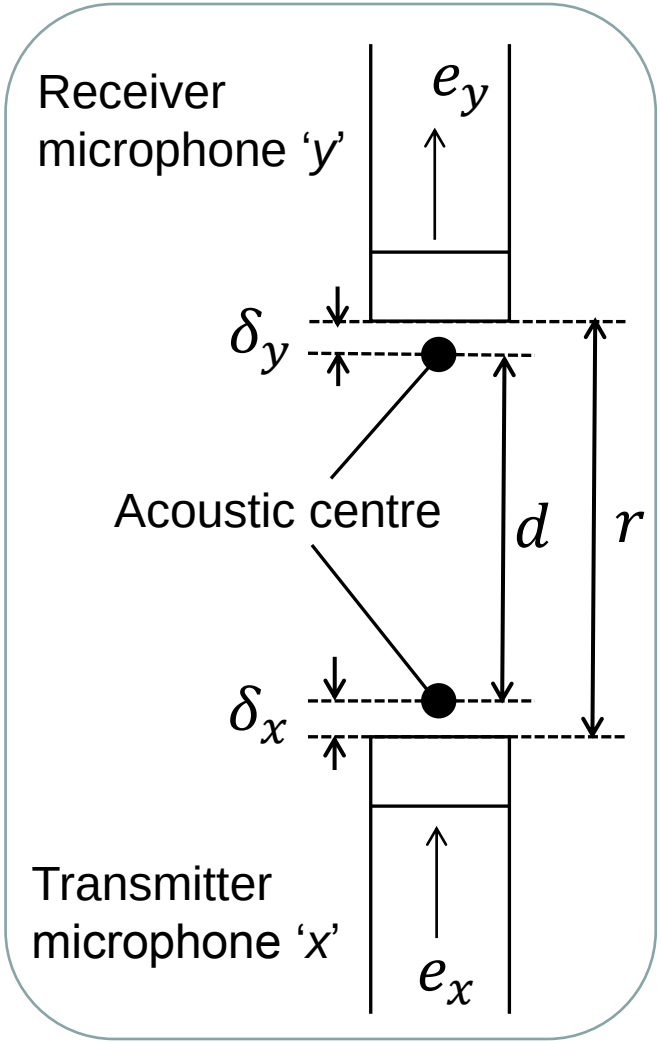


Sensitivity as a microphone = Sensitivity as a sound source

$$\left(\frac{e}{p}\right)_{i=0} = \left(\frac{q}{i}\right)_{p=0}$$

(Reciprocity)

Voltage Transfer Function (VTF)



- Voltage Transfer Function T_{xy}

$$T_{xy} \equiv \frac{e_y}{e_x} = \frac{1}{Z_{e,x}} M_x Z_{a,xy} M_y$$

where

$$Z_{a,xy} = j\frac{\rho f}{2d} e^{-jkd} e^{-\alpha r}, Z_{e,x} = 1/j\omega C_x$$

M_x, M_y : Free-field sensitivity of microphones ‘x‘ and ‘y’

C_x : Capacitance of microphone ‘x’

f : Frequency

ρ : Density of air

α : Attenuation in air

d : Distance between acoustic centres

r : Distance between microphone diaphragms

δ_x, δ_y : Distance between acoustic centre and diaphragm

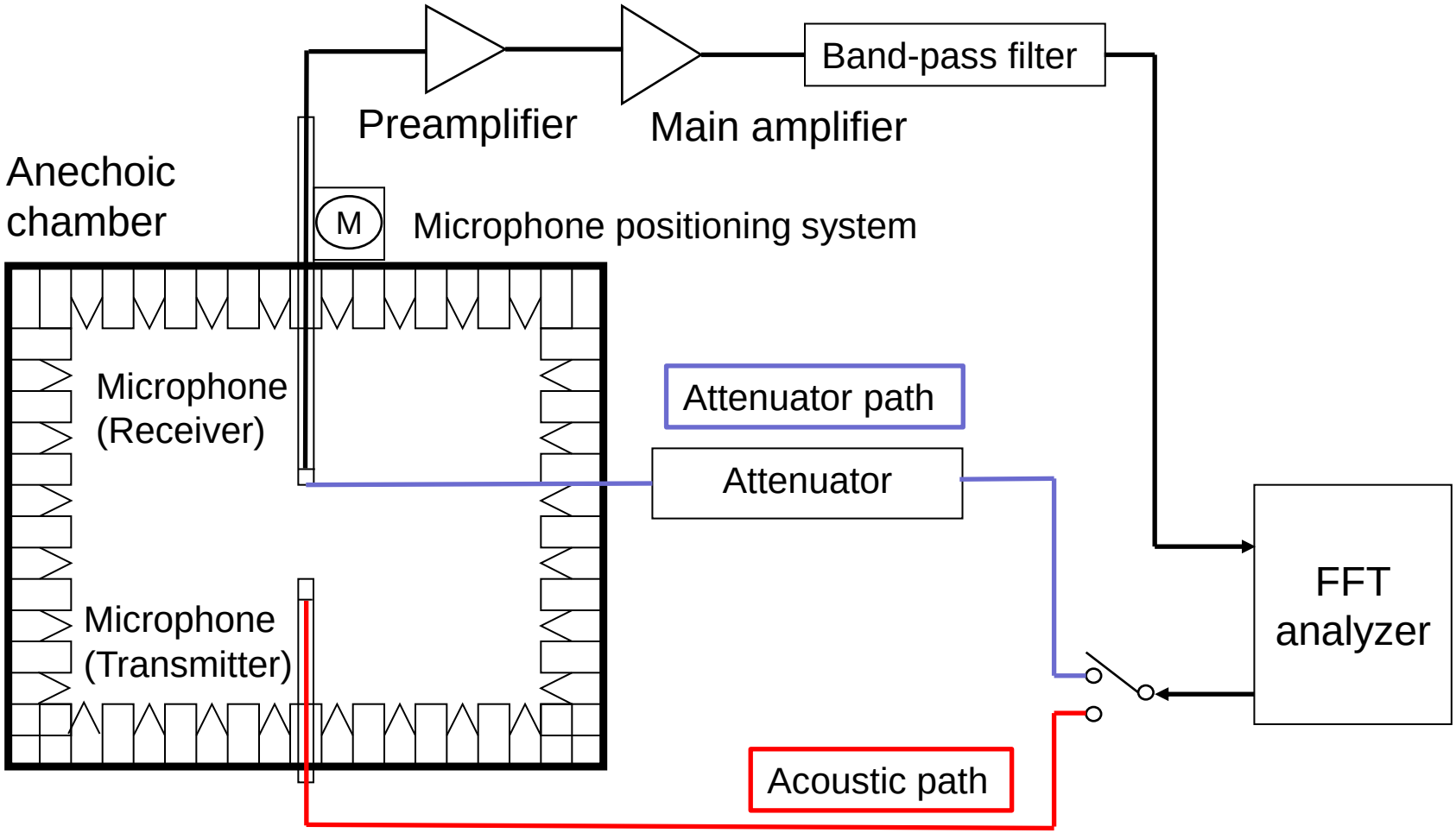
Calibration procedure at NMIJ

1. Preparation of three microphones
   (Indexed as ‘1’, ‘2’ and ‘3’)

2. Measurement
   - Environmental condition (Temp., Pressure, Hum.)
   - Electrical impedance (Capacitance) of mic. ‘2’
   - Voltage transfer Functions (VTFs)
     (1-2, 1-3 and 2-3)

3. Sensitivity calculation

Calibration system at NMIJ



Voltage transfer function →Measured by insert voltage technique

Uncertainty components

- Sound reflection
- Deviation from plane wave
- Repeatability
- Acoustic center
- Environmental conditions to sensitivity and air attenuation

Expanded uncertainty 1.0 dB (20 kHz to 100 kHz)

Development of rat-proof sound sources

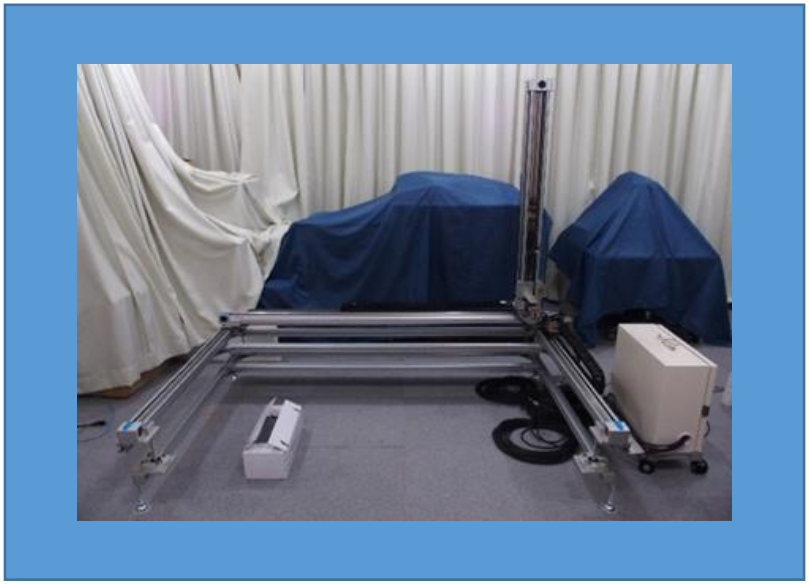
- used in the underground shopping mall etc.
  - Directivity
  - Sound reflection by the walls

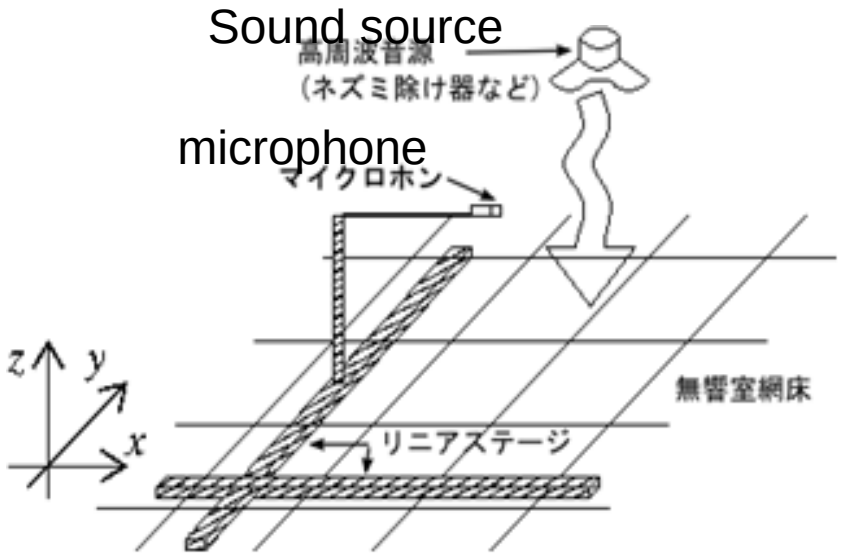
  →spatial distribution of the sound pressure

Graph was deleted from the point of confidentiality

Frequency dependence of the sound at some point

Microphone positioning system



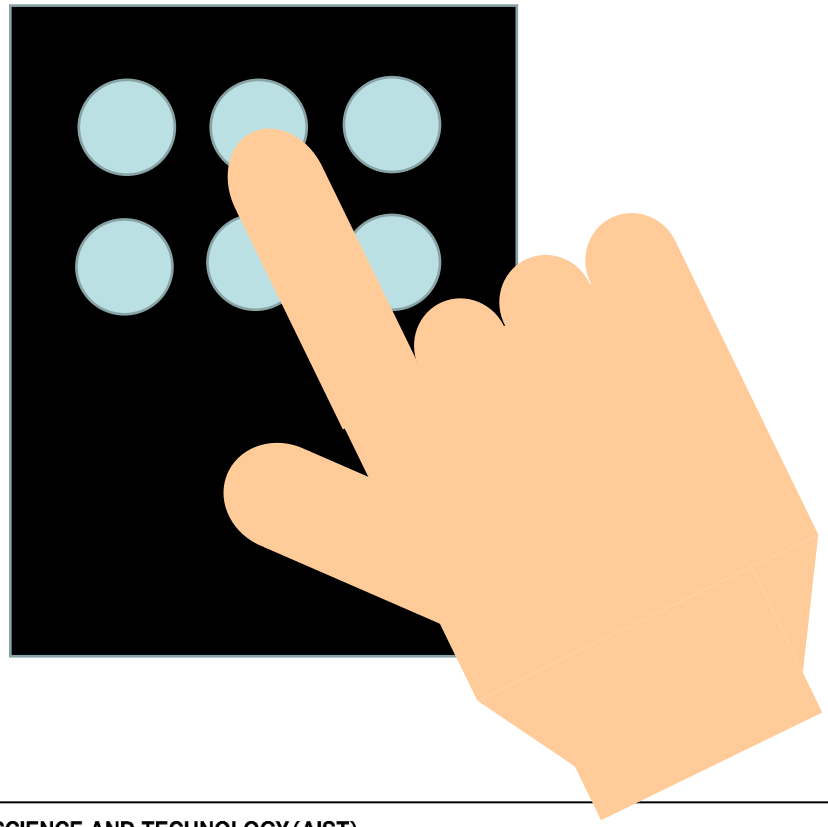


Linear stage

Tactile display for virtual reality

- Interaction between a floating image and touching sensation

→Focused ultrasound is superposed on the floating image



Summary

- Needs for precise measurement of airborne ultrasound
- Summary of free-field reciprocity calibration of WS3 microphones at NMIJ
- Some applications of airborne ultrasound

Thank you for attention