中国计量科学研究院
National Institute of Metrology

Acoustic Calibration Service in Automobile Field at NIM, China

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Contents

1 Overview of Calibration Services

- As people pay more attention to comfortability in automobile, NVH performance is becoming more and more important now.

20% of R & D expenses is for NVH

Policies and Regulations

Technology capability

Competitions

Customers' needs

1 Overview of Calibration Services

- A lot of systems are employed in NVH test, especially in acoustics field;
- To make the test result accurate, consistent and traceable, the measurement equipment or devices need to be calibrated regularly;
- So many automobile manufacturers in China are becoming the customers of NIM.

NVH Test is Important !!!

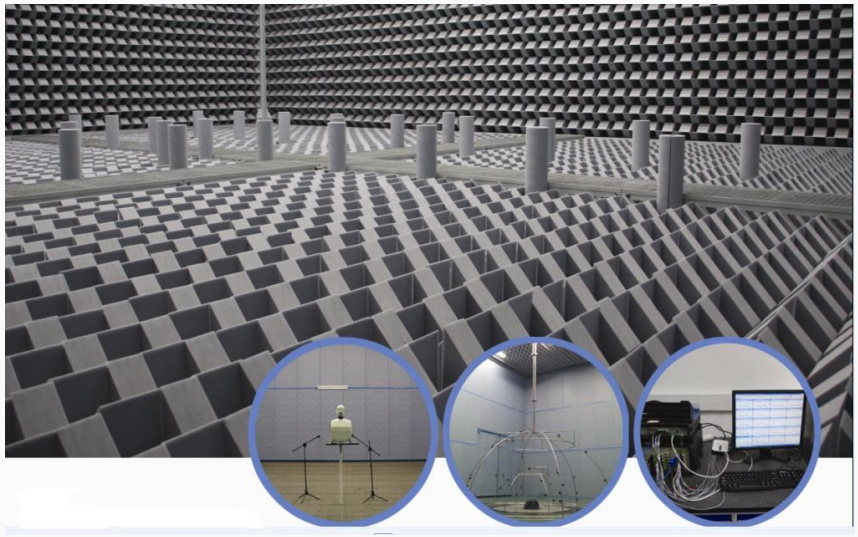
1 Overview of Calibration Services

- Statistics of calibration device in acoustic every year:
  - Anechoic room
  - Microphones ;
  - Multi-channel sound analyzer;
  - Sound Level Meter;
  - Sound Calibrator;
  - Power Amplifier;
  - Conditioning Amplifier or Measuring Amplifier;
  - Acoustic filer.

Contents

2 Anechoic Room Calibration

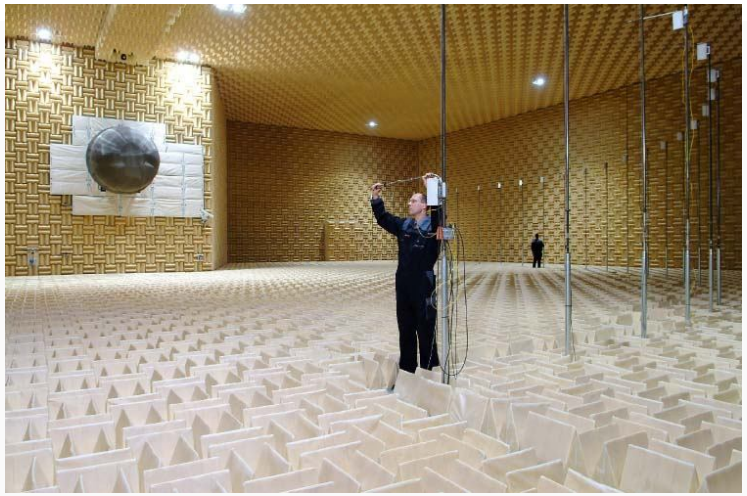
- Introduction
  - Providing free field space for acoustic experiments;
  - 99%+ absorption for sound in hearing frequency range;
  - Low background noise;



- Classification
  - Anechoic room----Precision Measurement;
  - Hemi-anechoic room----large size machine;

2 Anechoic Room Calibration

- Anechoic room application
  - Acoustic performance test for electro-acoustic component or unit (loudspeaker, hearing aids)
  - Microphone and SLM calibration
  - Precision acoustic recording;
  - Low noise test;



2 Anechoic Room Calibration

- Hemi-Anechoic room application
  - Sound power Measurement
    - Standard sound source;
    - household appliances (washing machine, air conditioner);
    - IT products (computer, server)
  - In Automobile field
    - pass-by test;
    - engine or motor test;
    - components test;
    - material absorption or insulation test

2 Anechoic Room Calibration

- Calibration according to:
  - International Standards:
    - ISO 3745-2012 Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure - Precision methods for anechoic rooms and hemi-anechoic rooms
  - National Standards:
    - GB/T 6882-2008 Annex A General procedures for qualification of anechoic and hemi-anechoic rooms
    - JJF 1147-2006 Calibration Specification for Acoustic Performance of Anechoic Room and Hemi-Anechoic Room

2 Anechoic Room Calibration

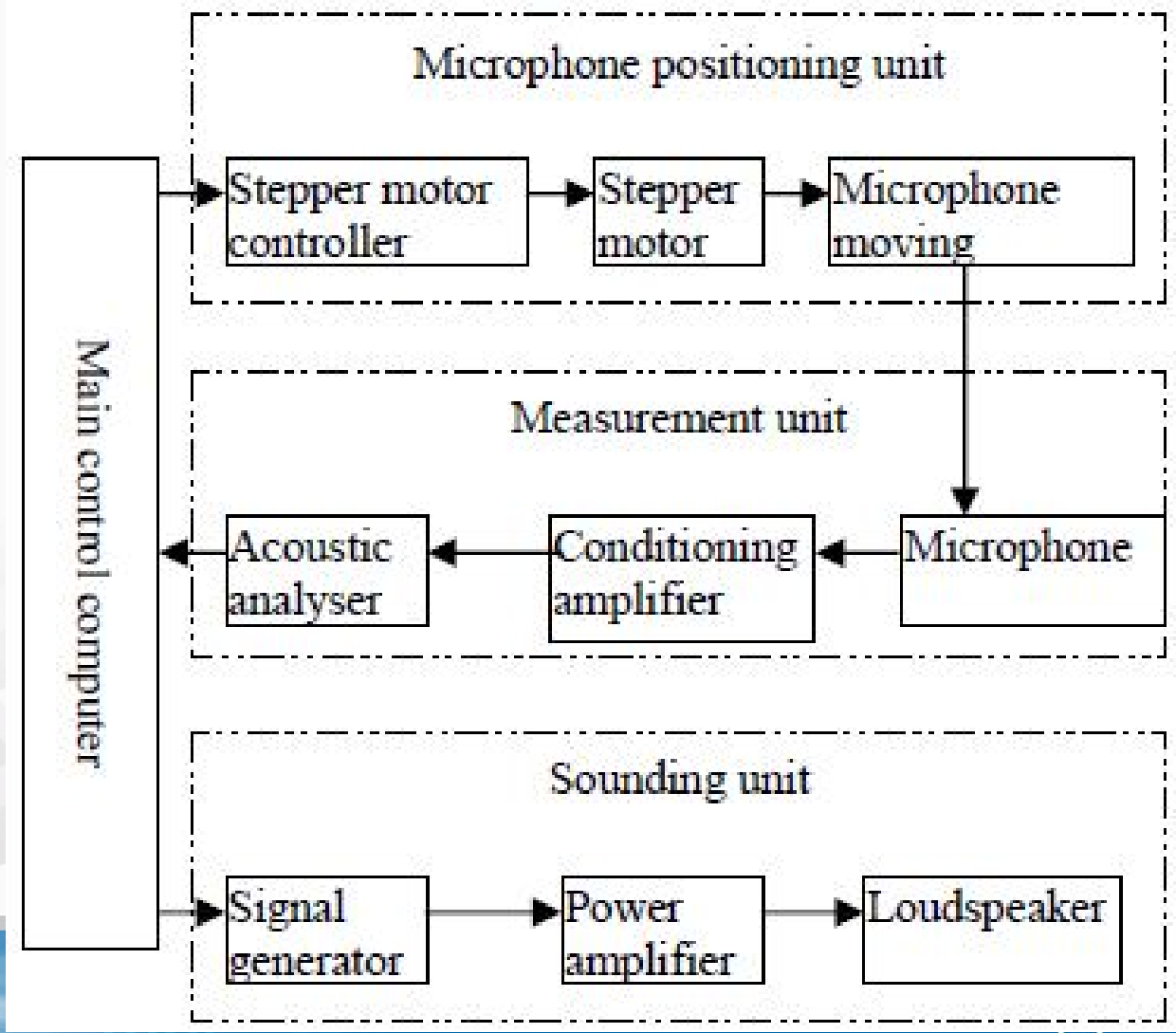
- **Calibration Parameters:**
  - **Frequency Range and Space Range of Free Field :**
    - **Maximum deviation between measured SPL and theoretical SPL using inverse square law;**
    - **For electro-acoustic test, normally ±1dB;**
    - **For noise test, table below,**

Type of test room	One-third-octave band frequency Hz	Allowable deviation dB
Anechoic (free-field)	≤630	±1,5
	800 to 5 000	±1,0
	≥6 300	±1,5
Hemi-anechoic (hemi-free-field)	≤630	±2,5
	800 to 5 000	±2,0
	≥6 300	±3,0

  - **Background Noise: 15 dB lower than UUT**

2 Anechoic Room Calibration

- **Calibration System:**

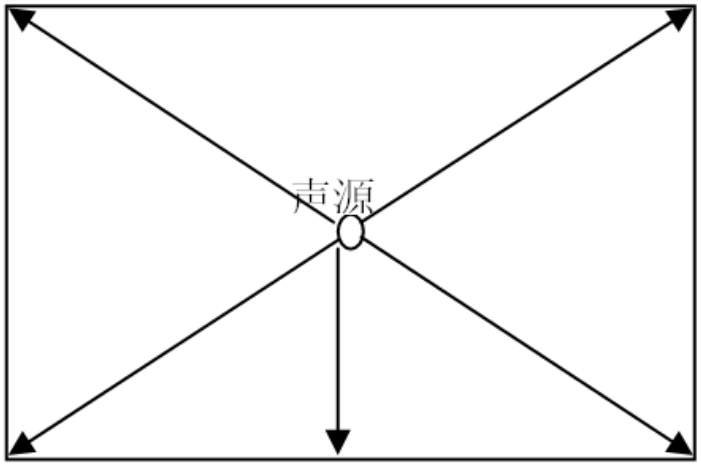


2 Anechoic Room Calibration

- **Sound Source Installation:**
  - **Anechoic room: The test sound source shall be located so that the assumed position of the acoustic centre coincides as closely as possible with a point identified as the geometric centre of the measurement sphere, preferably in the centre of the room.**
  - **Hemi-Anechoic room: The test sound source shall be located so that the assumed position of the acoustic centre coincides as closely as possible with a point identified as the geometric centre of the measurement hemisphere, preferably in the centre of the floor of the room. the acoustic centre of the test source is situated as close as possible to, but in any case should not be greater than 150 mm from, the reflecting floor.**

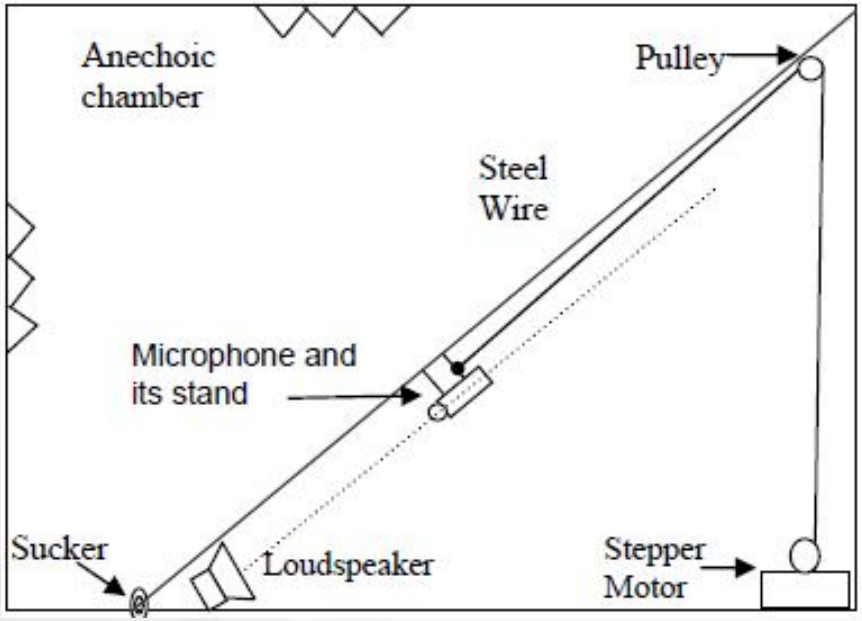
2 Anechoic Room Calibration

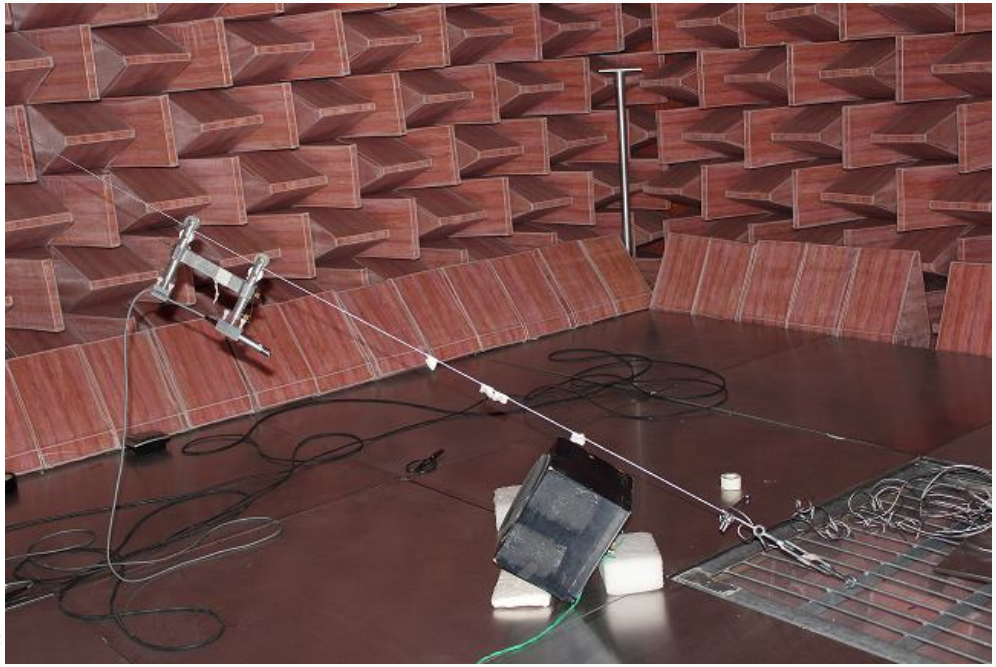
- **Microphone traverse:**
  - **Normally, the lines from the geometric centre of the measurement sphere or hemisphere to the room corners and lines normal to the wall surfaces. (at least 3 lines)**
  - **For anechoic room: Another choice is line parallel to the walking net.**
  - **Interval of moving should be less than 0.1m and the number of test points should be more than 10.**



2 Anechoic Room Calibration

- **Microphone traverse:**





2 Anechoic Room Calibration

- Test Signals:
  - Pure tone signal
  - Noise signal:
    - White noise
    - Pink noise

- Measuring SPL:
  - First point: 0.5 m away from assumed acoustic center of sound source
  - All measured SPL at least 15 dB higher than background noise:
  - Below 125 Hz and above 4000 Hz, using 1/3 octave bands; between 125 Hz and 4000 Hz, using octave bands.
  - The upper frequency limit normally 10 kHz, but could be extended to 20 kHz.

2 Anechoic Room Calibration

- **Inverse square law:**

$$L_p(r_i) = 20 \lg \left[\frac{a}{r_i - r_0} \right] \text{dB}$$

$$r_0 = -\left[\frac{\sum_{i=1}^{M} r_i \sum_{i=1}^{M} r_i q_i - \sum_{i=1}^{M} r_i^2 \sum_{i=1}^{M} q_i}{\sum_{i=1}^{M} r_i \sum_{i=1}^{M} q_i - M \sum_{i=1}^{M} r_i q_i} \right]$$

$$a = \frac{M r_0^2 + \sum_{i=1}^{M} r_i^2 - 2 r_0 \sum_{i=1}^{M} r_i}{\sum_{i=1}^{M} r_i q_i - r_0 \sum_{i=1}^{M} q_i};$$

$$q_i = 10^{-0,05 L_{pi}}$$

a is a constant related to the sound power emitted from the test sound source:

r_i is the distance of the ith measurement position from the centre of the measurement sphere or hemisphere;

r_0 is the collinear offset of the acoustic centre along the axis of the microphone traverse — it is a measurement of the separation between the acoustic centre of the source and the origin of the microphone traverse, whose apparent position is given by:

where L_{pi} is the sound pressure level at the ith measurement position, in decibels;

M is the number of measurement positions along each microphone traverse within the region where the inverse square law is followed (assumes that data points near the end of a traverse may be discarded).

2 Anechoic Room Calibration

- **The automatic calibration program based on B&K Pulse System:**

2 Anechoic Room Calibration

- **Background Noise Test:**
  - **The lower limit depends on the microphone and analyzer:**
    - **B&K 4955：5 dB（A）**
    - **B&K 4179+2660：-2.5 dB（A）**
    - **B&K 4190：14.6 dB （A）**
  - **Test points:**
    - **Geometric center or working area**
  - **Using A weighting SPL and 1/3 octave band SPL.**

2 Anechoic Room Calibration

- **The Calibration Report to Customers:**

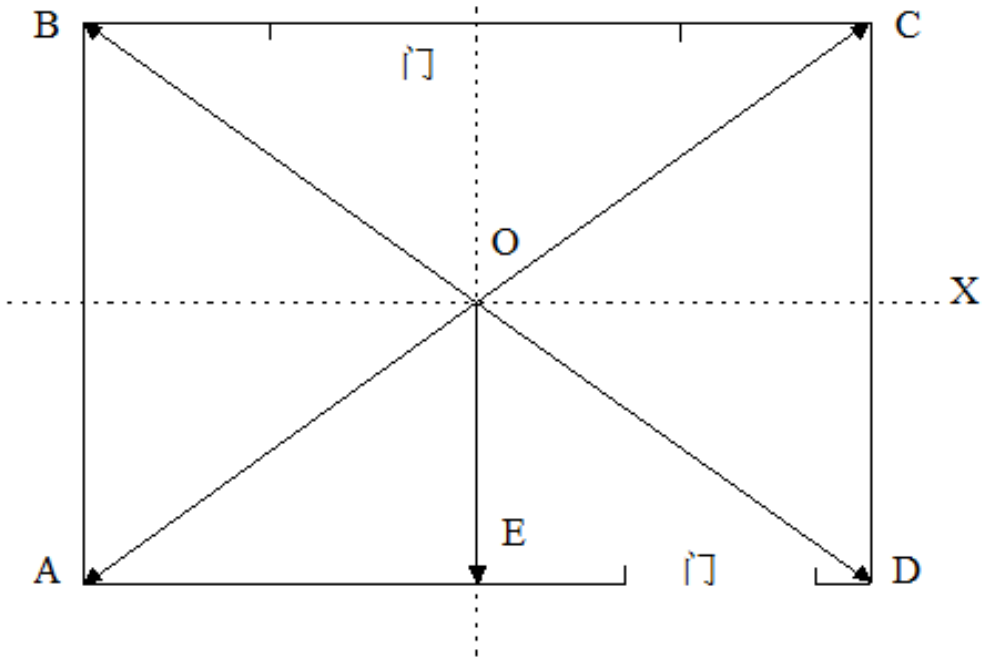


图 1 测试线方向示意图

表 1 GB/T 6882 标准对半消声室自由声场的允差要求

1/3 倍频程中心频率(Hz)	允差(dB)
≤630	±2.5
800～5000	±2.0
≥6300	±3.0

2 Anechoic Room Calibration

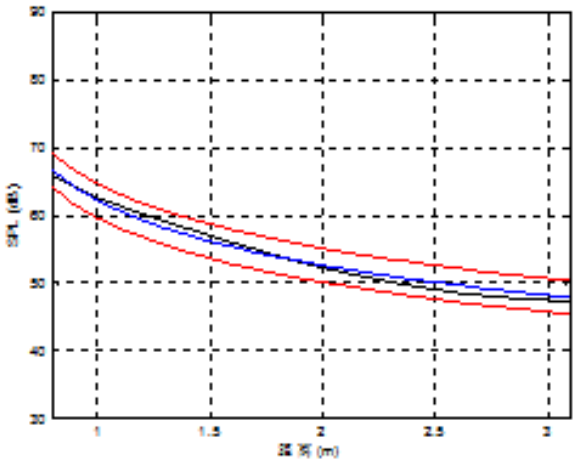
- **The Calibration Report to Customers:**

表 2　测试线上满足允差的最长距离

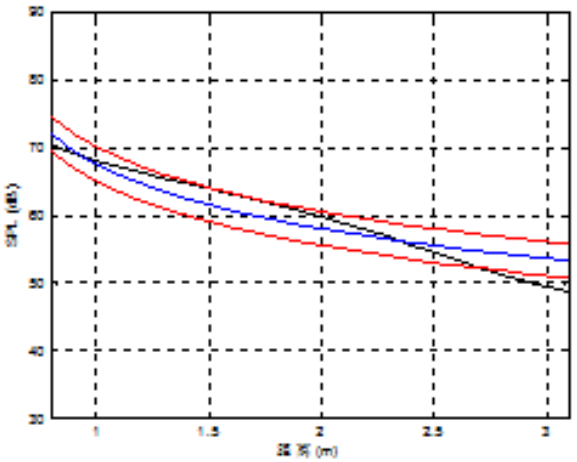
频率/Hz	OA/m	OB/m	OC/m	OD/m	OE/m
50	3.10	3.30	3.20	3.20	3.10
63	2.70	2.80	2.40	2.60	2.50
80	3.10	3.30	3.20	3.20	3.10
100	3.10	3.30	3.20	3.20	3.10
125	3.10	3.30	3.20	3.20	3.10
160	3.10	3.30	3.20	3.20	3.10
200	3.10	3.30	3.20	3.20	3.10
250	3.10	3.30	3.20	3.20	3.10
315	3.10	3.30	3.20	3.20	3.10
400	3.10	3.30	3.20	3.20	3.10
500	3.10	3.30	3.20	3.20	3.10
630	3.10	3.30	3.20	3.20	3.10
800	3.10	3.30	3.20	3.20	3.10
1000	3.10	3.30	3.20	3.20	3.10
1250	3.10	3.30	3.20	3.20	3.10
1600	3.10	3.30	3.20	3.20	3.10
2000	3.10	3.30	3.20	3.20	3.10
2500	3.10	3.30	3.20	3.20	3.10
3150	3.10	3.30	3.20	3.20	3.10
4000	3.10	3.30	3.20	3.20	3.10
5000	3.10	3.30	3.20	3.20	3.10

2 Anechoic Room Calibration

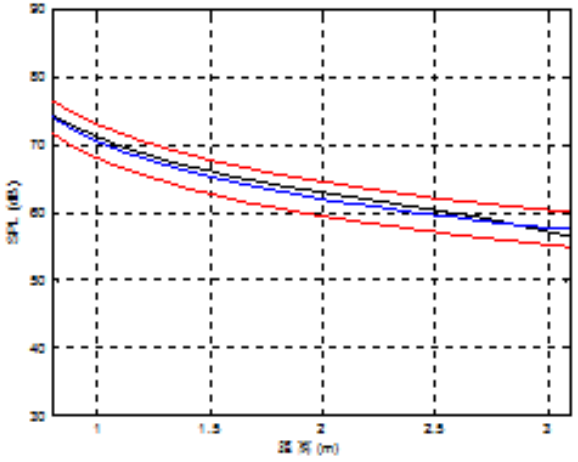
- **The Calibration Report to Customers:**



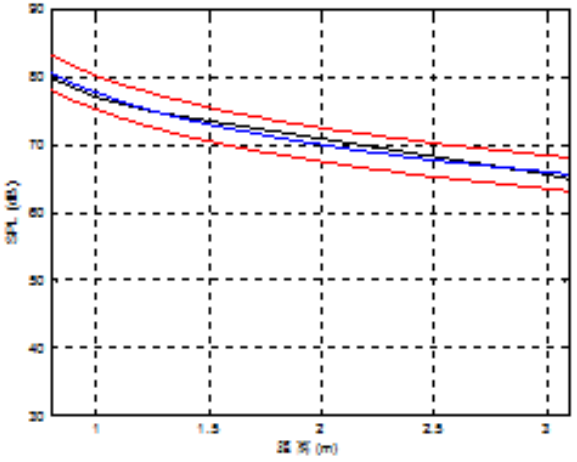
OA-50 Hz



OA-63 Hz



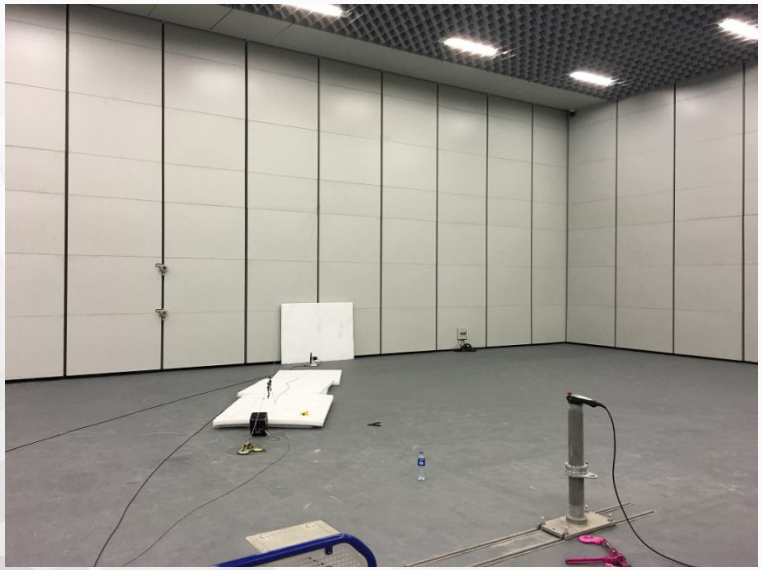
OA-80 Hz

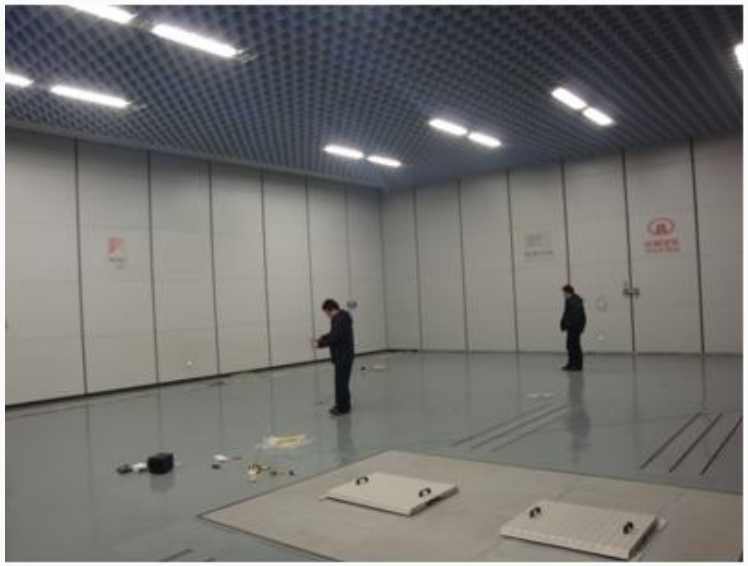


OA-100 Hz

2 Anechoic Room Calibration

- **Some Anechoic and Hemi-anechoic Rooms Calibrated by NIM:**





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3 Multi-Channel Sound Analyzer Calibration

Brüel & Kjær
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HEAD acoustics®

LMS
ENGINEERING INNOVATION

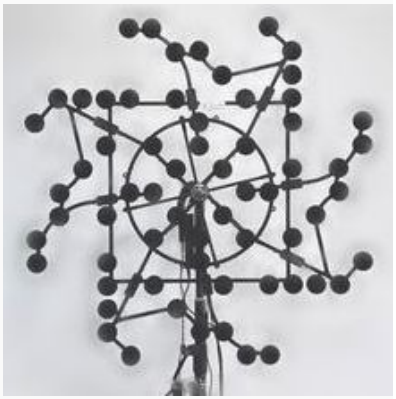
BSWA TECH

HengSheng electronics 恒升电子

爱华仪器
AIHUA INSTRUMENTS

3 Multi-Channel Sound Analyzer Calibration

- Applications:
  - Sound power measurement
  - Sound source identification (Sound camera)
  - Pass-by test:
  - Source path contribution test (understand routes sound and vibration travel from source to receiver)



3 Multi-Channel Sound Analyzer Calibration

- Calibration according to:
  - International Standards:
    - IEC 61672-3: Electroacoustics - Sound level meters - Part 3: Periodic tests
  - National Standards:
    - JJF 1288-2011: Calibration Specification for Multi—Channels Sound Analyzers

3 Multi-Channel Sound Analyzer Calibration

- **Calibration Parameters:**

Number	Parameters	same as SLM
1	Indication at the calibration check frequency	Y
2	Self-generated noise	Y
3	Electrical signal tests of frequency weightings	Y
4	Frequency and time weightings at 1 kHz	Y
5	Level linearity	Y
6	Tone-burst response	Y
7	Crosstalk	N
8	Channel consistency	N
9	Output frequency response	N
10	Output frequency accuracy	N
11	Output amplitude accuracy	N
12	Output distortion	N
13	White noise spectrum	N
14	Pink noise spectrum	N

3 Multi-Channel Sound Analyzer Calibration

- **Crosstalk:**
  - **8 kHz steady-state sine signal is applied to one of the channels, the input of the other connected to equipment ground, record the signal level of the input signal channel and other channels. The difference between the output signal level of the access channel and other signal channels is calculated.**

3 Multi-Channel Sound Analyzer Calibration

- **Channel consistency:**
  - **Apply 1 kHz, 1V sine signal to two channels at the same time**
  - **Recording the signal amplitude from the two channels and calculating amplitude ratio;**
  - **Using cross correlation function to get the phase difference from two channels.**

3 Multi-Channel Sound Analyzer Calibration

- **Output Signal Calibration----Pure tone signal:**

  - **Frequency accuracy: universal frequency counter**

    10 Hz, 20 Hz, 50 Hz, 100 Hz, 200 Hz, 500 Hz, 1 kHz, 2 kHz, 5 kHz, 10 kHz and 20 kHz

  - **Amplitude accuracy: Voltmeter**

    50 mV, 100 mV, 1 V, 2 V, 4 V, 5 V

  - **Frequency response: Voltmeter** → $\Delta L = 20 \lg \frac{U_x}{U_0}$

    10 Hz ~ 20 kHz

  - **Distortion: distortion analyzer**

    amplitude set to maximum, measure at 20 Hz, 200 Hz, 1 kHz, 2 kHz and 20 kHz

3 Multi-Channel Sound Analyzer Calibration

- **Output Signal Calibration----Noise signal:**
  - **Measure spectrum from 31.5 Hz ~ 16 kHz for octave band or from 20 Hz ~ 20 kHz for 1/3 octave band.**

Thank You for Your Attention