MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Calibration of Head and Torso Simulator in accordance with the Recommendation ITU-T P.58 (05/2013)

AU, Chi-ho, Andrew[1]
LAM, Hoi-shan, Brenda[2]
KWAN, Yu-cheung[3]
TUNG, Kwok-keung, Angus[3]
Standards and Calibration Laboratory
36/F., Immigration Tower, 7 Gloucester Road, Wanchai, Hong Kong

ABSTRACT

The Standards and Calibration Laboratory (SCL) has set up a system for the calibration of Head and Torso Simulators (HATS) in accordance with the Recommendation ITU-T P.58 (05/2013). HATS is a device that accurately reproduces the sound transmission and sound pick-up characteristics of the median head and torso of adult humans. They are widely used in the development of hearing aids, hearing protectors, telephone handsets, headsets and microphones etc. in both the audiological and telephony industries. Therefore, the SCL has developed the calibration system to provide the respective calibration service in Hong Kong.

Keywords: HATS, Calibration, Acoustic Measurement
I-INCE Classification of Subject Number: 72

1. INTRODUCTION

A HATS consists of an artificial head and a torso, it simulates the acoustical properties as an average human, including the sound transmission and sound pick-up characteristics. The HATS calibration system at the SCL comprises two reference microphones, a sound source with a power amplifier, a pistonphone and a signal analyzer with control software installed on a personal computer. The calibration is divided into two parts: i) measuring the maximum deliverable sound pressure level and the 2nd and 3rd harmonic distortions of the artificial mouth of the simulator; ii) measuring the free-field frequency responses of the left and right artificial ears of the HATS with sound incident at 0°. The measurements are performed in an anechoic chamber in which the free-field conditions are validated according to the recommendation. Details of the calibration system will be discussed in the following sections.

[1] andrew.au@itc.gov.hk
[2] hslam@itc.gov.hk
[3] scl_av@itc.gov.hk

2. PREPARATION FOR CALIBRATION

Calibration of HATS involves free-field acoustic measurements. As specified in the ITU-T recommendation, the test space and the sound source shall provide plane progressive waves in free-field conditions in the frequency range of 100 Hz to 10 kHz. Moreover, the sound pressure level of extraneous background noise shall meet the required limit. Therefore, the test space in the anechoic chamber has been validated before the calibration is started.

Another factor that affects much in the measurement result is the accuracy of alignment. To facilitate the alignment work, a tailor-made fixture has been designed to either support the HATS or hold the reference microphone by using different mechanical assemblies. In addition, with the aid of a cross-line laser pointer and the use of time-selective measurement technique, the alignment of the HATS and the reference microphone has been done accurately which dramatically improves the measurement uncertainty in this aspect.

Moreover, a tailor-made adaptor as described in the international standard of microphone calibration IEC 61094-5:2016 has been fabricated for calibration of the quarter-inch reference microphones by comparison with the laboratory's half-inch reference standard microphone. This ensures the proper metrological traceability to the SI units.

2.1 Validation of Free Sound Field Conditions

To meet the criteria of free-field conditions as specified in the ITU-T recommendation (the sound pressure levels in the test space shall be within the specified limits), the distance between the sound source and the HATS Reference Point (HRP) is calculated to be longer than 2.4 m due to the Inverse Square Law. The law holds true when the sound field is sufficiently far away from the source that the sound pressure level is inversely proportional to the square of the distance from the sound source. There are no reflections or reverberation in this free sound field conditions.

Since both the inside length and width of the anechoic chamber, wedge tip to wedge tip, are 2.7 m only (inner dimensions of the chamber between the wedges: 2.7 m × 2.7 m × 1.4 m), the sound source and the HRP are located at the opposite corners on a diagonal of the chamber. As specified by the ITU-T recommendation, there are six measurement points located 250 mm away from the test point as demonstrated in Figure 1. All these six measurement points have been checked to comply with the specified requirements.

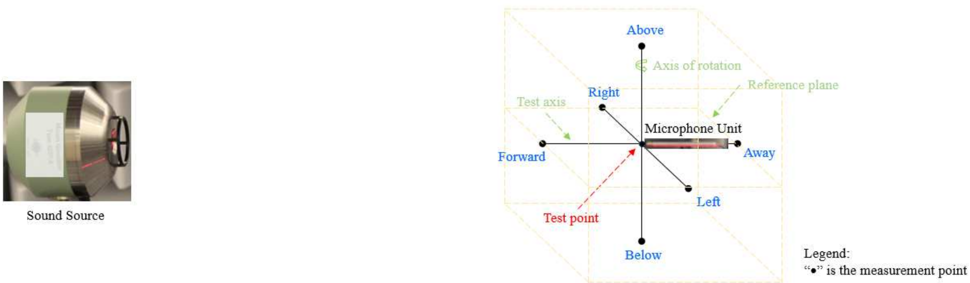

Figure 1. *Measurement points for validation of free-field conditions*

Besides, the background noise of the anechoic chamber has also been measured to ensure that the specified limit on the background noise in free-field conditions is not exceeded.

2.2 Alignment of Reference Microphone and HATS

As described previously, a tailor-made fixture has been designed which consists of two translation stages with micrometers stacked in right-handed XY orientation allowing to move the HATS or reference microphone in the X or Y direction slowly and smoothly. Moreover, the fixture is also flexible in adjusting the azimuth angle precisely. Figures 2a and 2b show the tailor-made fixture for holding the HATS and the reference microphone with different mechanical assemblies.

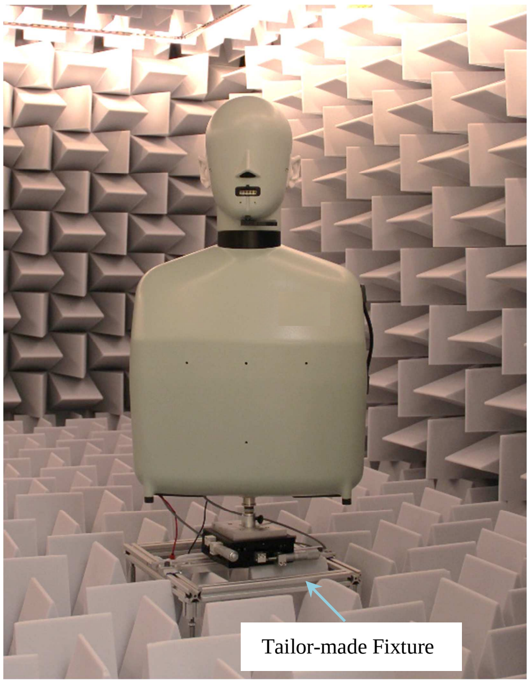

Figure 2a. *Tailor-made fixture holding the HATS*

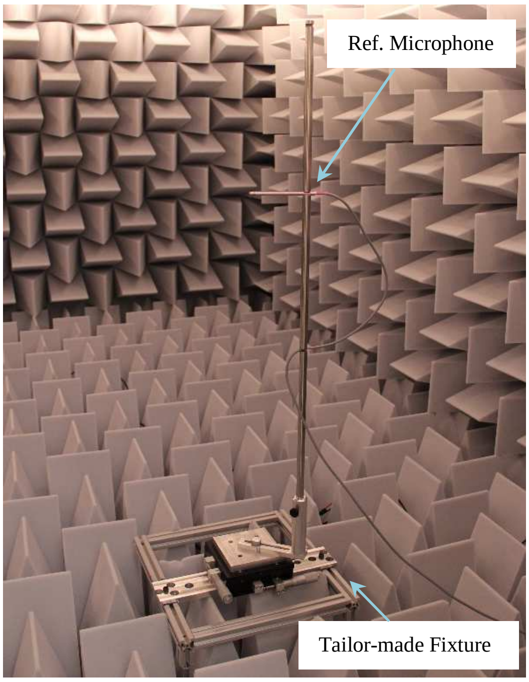

Figure 2b. *Tailor-made fixture holding the reference microphone*

There are two alignment techniques (optical technique and time-selective measurement technique) used in setting up the calibration system. The coincidence of the incident and reflected laser beams of the cross-line laser pointer on a mirror attached on the lip ring of the sound source is observed when the optical alignment has been done appropriately. The optical alignment can be achieved easily with the use of the tailor-made fixture. Figure 3 shows the optical alignment setup of the HATS.

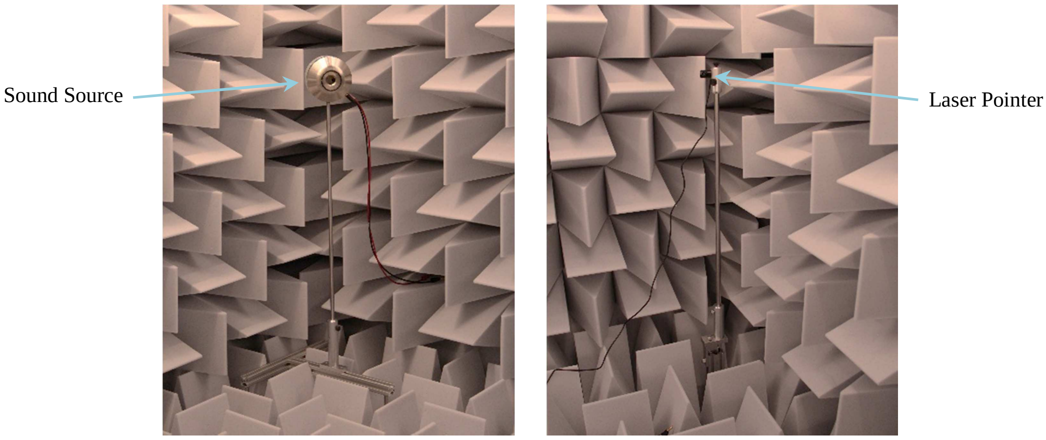

Figure 3. *Optical alignment setup of HATS*

In time-selective measurement technique, the distance travelled by the impulse signal generated from the sound source to the sound receiver which can either be the reference microphone or the left / right ear simulators of the HATS is calculated accurately by multiplying the speed of sound in air and the time elapsed. Therefore, any deviation between the pre-set time window and the impulse response is observed if there is an alignment error. A fine adjustment can be done with the use of the tailor-made fixture. Alignment with millimeter-level accuracy could be provided by using this measurement technique.

In Figure 4, the impulse responses of the left and right ear simulators are displayed to check if the distances between the sound source and the left and right ear simulators are the same. Fine adjustment could be made on the azimuth angle of the HATS if deviation in the peak locations of the impulse responses is observed.

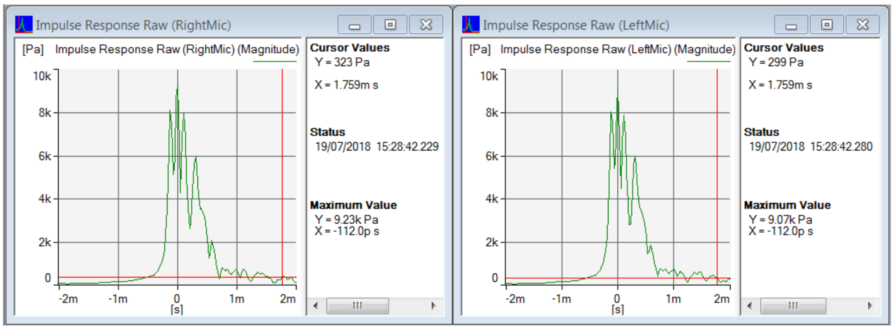

Figure 4. *Measured impulse responses of the ear simulators of the HATS*

Moreover, this measurement technique also helps to eliminate the unwanted reflections from the surroundings due to the imperfection of the anechoic chamber and the mounting of the equipment. In Figure 5, the impulse response of an ear simulator before and after windowed is demonstrated. It is observed that the unwanted reflections were filtered.

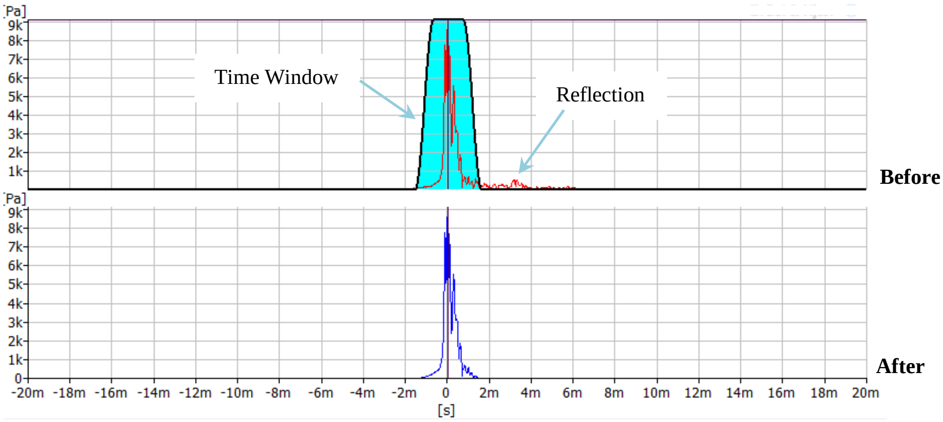

Figure 5. *Impulse response of an ear simulator before and after windowed*

2.3 Calibration of Quarter-inch Microphone

There are two quarter-inch microphones used in the calibration system. One is for pressure-field measurements and the other is for free-field measurements. To ensure the accuracy of acoustic measurements and proper metrological traceability to the SI units, a quarter-inch microphone calibration system is developed. As described in the International Standard IEC 61094-5:2016, a tailor-made adaptor has been fabricated to mount the quarter-inch microphone (with the grid removed) into a comparison coupler where the quarter-inch microphone and the reference microphone B&K 4180 are positioned face-to-face and separated by a very small distance as specified in the IEC standard. Figure 6 shows the tailor-made adaptor for the quarter-inch microphone calibration.

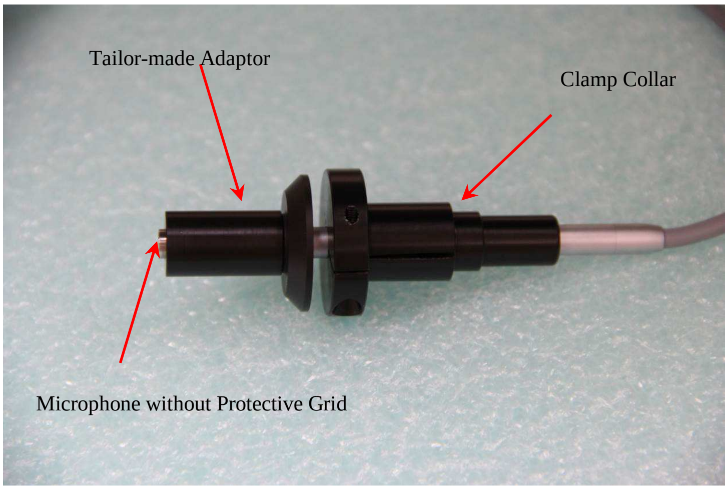

Figure 6. *Tailor-made adaptor for quarter-inch microphone calibration*

3. CALIBRATION SETUP AND METROLOGICAL TRACEBILITY

In the previous section, the preparation work for the calibration of HATS are introduced. In this section, the HATS talker and ears calibration systems are introduced and discussed.

3.1 HATS Talker Calibration System

The HATS talker calibration system comprises a personal computer with control software, a pressure-field reference microphone, a pistonphone, a barometer, a power amplifier and a signal analyzer. All the measurements are performed in the laboratory's anechoic chamber. A photo of all major instruments used in this calibration is shown in Figures 7a and 7b.

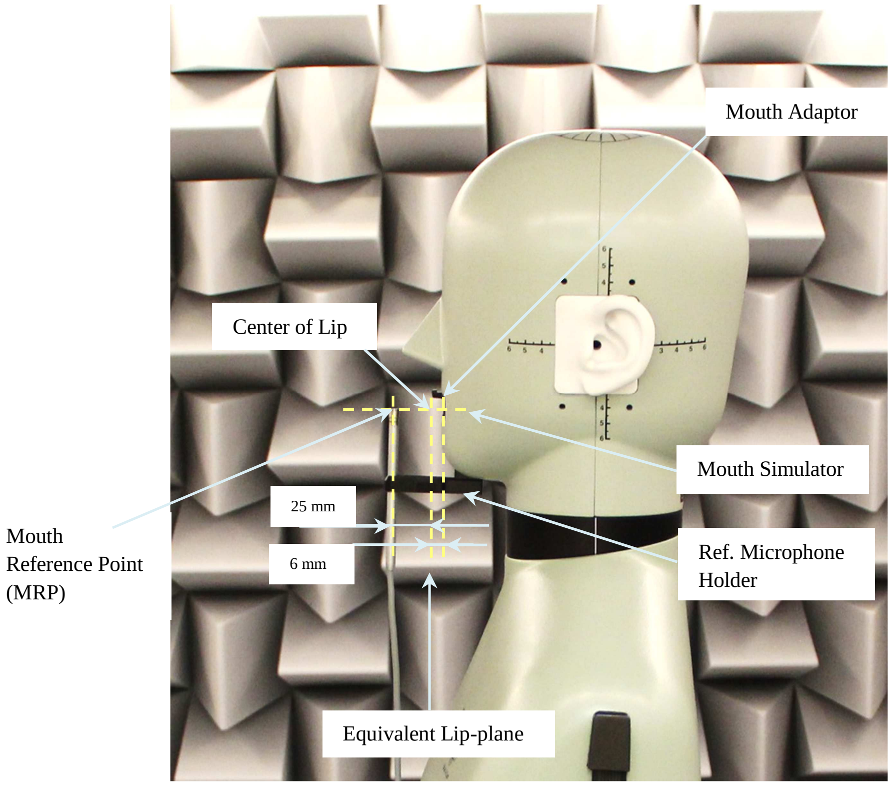

Figure 7a. *Reference points of the HATS mouth simulator*

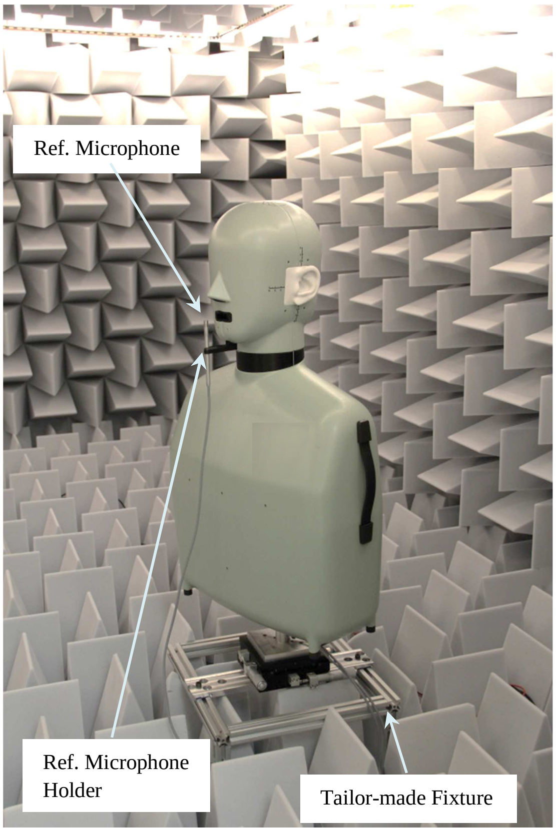

Figure 7b. *Calibration setup for sound emission measurements*

The connection diagram of the HATS talker calibration system is shown in Figure 8. The acoustic signal generated by the HATS mouth under test is measured at the Mouth Reference Point (MRP) by the pressure-field working standard microphone with protection grid installed and the signal analyzer. The pistonphone and the barometer are used to calibrate the reference microphone to ensure the proper metrological traceability to the SI units at the measurement conditions.

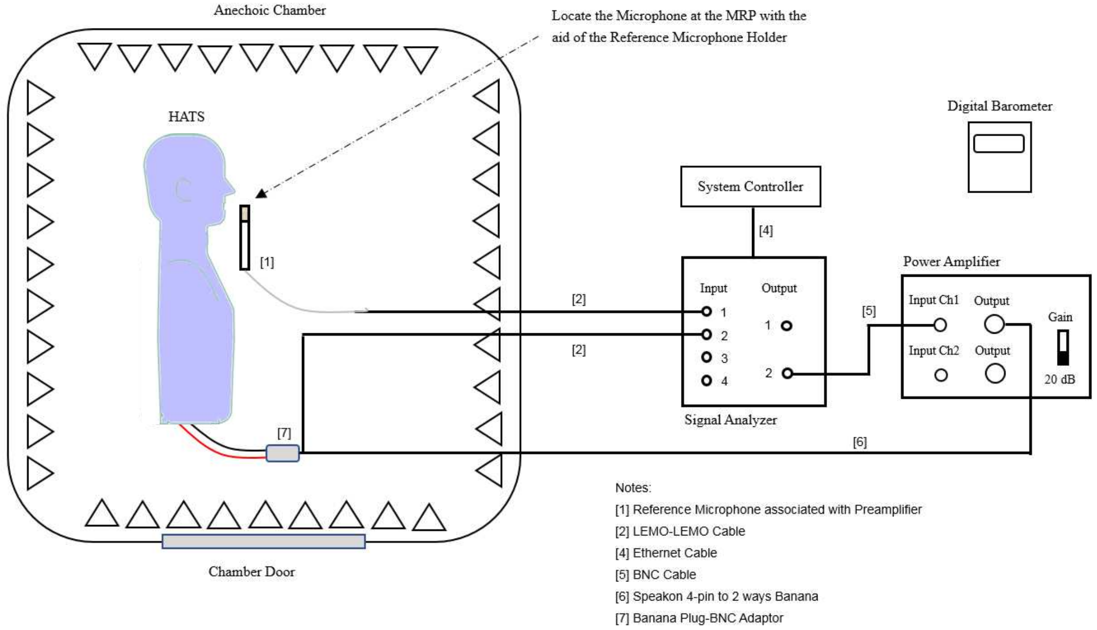

Figure 8. *Connection diagram for sound emission measurements*

Measurement results of the maximum deliverable sound pressure level and the 2nd and 3rd harmonic distortions are compared to the specified limits for compliance checking. The acoustic quantities are metrologically traceable to the laboratory's reference microphone which is calibrated by the reciprocity method while the AC and DC voltages are metrologically traceable to the laboratory's AC/DC voltage transfer standard and the Josephson Array Voltage Standard (JAVS) respectively.

The uncertainty components for calibration of the 2nd and 3rd harmonic distortions of the HATS mouth include: service uncertainty of the signal analyzer, uncertainties due to repeatability of measurements and misalignment of the reference microphone at the MRP of the HATS. More uncertainty components such as service uncertainties of the reference microphone and the pistonphone as well as the uncertainties due to environmental conditions and the discrimination error of the HATS talker calibration system would be considered in the measurement of the maximum deliverable sound pressure level. These uncertainties are either obtained from our calibration reports or evaluated experimentally.

The dominant uncertainty component is the measurement uncertainty due to misalignment of the reference microphone at the MRP in the measurement of the maximum deliverable sound pressure level while the service uncertainty of the signal analyzer is regarded as the major factor in the calibration of the 2nd and 3rd harmonic distortions. The calibrations cover an extensive range from 10 Hz to 10 kHz and the best measurement uncertainties are 0.5 dB and 1.5 % respectively.

3.2 HATS Ears Calibration System

The HATS ears calibration system comprises a personal computer with control software, a free-field reference microphone, a pistonphone, a barometer, a sound source with a power amplifier and a signal analyzer. All the measurements are performed in the laboratory's anechoic chamber. A photo of all the major instruments used in this calibration is shown in Figure 9.

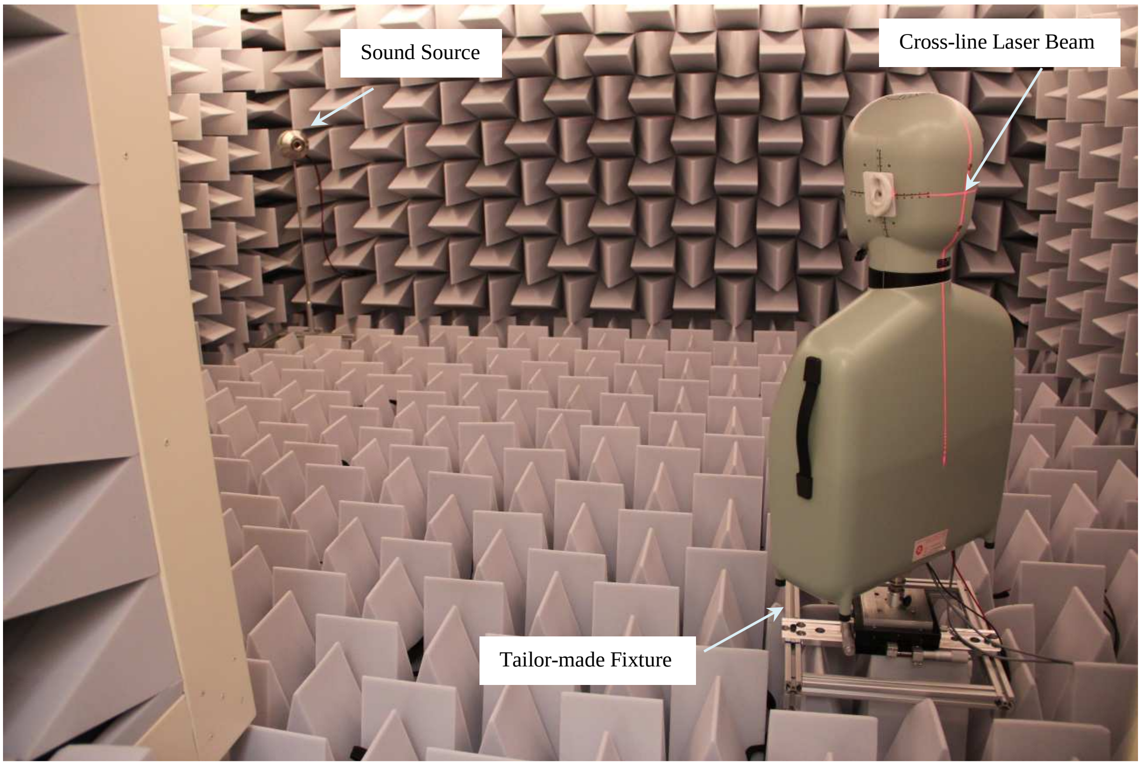

Figure 9. *Calibration setup for sound pick-up measurements*

The connection diagram of the HATS ears calibration system is shown in Figure 10a and 10b. The calibration can be divided into two parts: i) measurement of the acoustic pressure generated by the sound source at the HRP in a free sound field with the HATS under test absent; ii) measurement of the acoustic pressure at the ear-Drum Reference Points (DRP) of the HATS under test by the left and right occluded ear simulators simultaneously with the HATS under test installed at the HRP. The difference, in dB, between the measured acoustic pressures is known as the sound pick-up free-field frequency response of the HATS and is compared to the specified limits for compliance checking. The acoustic quantities are metrologically traceable to the laboratory's reference microphone which is calibrated by the reciprocity method while the AC and DC voltages are metrologically traceable to the laboratory's AC/DC voltage transfer standard and the Josephson Array Voltage Standard (JAVS) respectively.

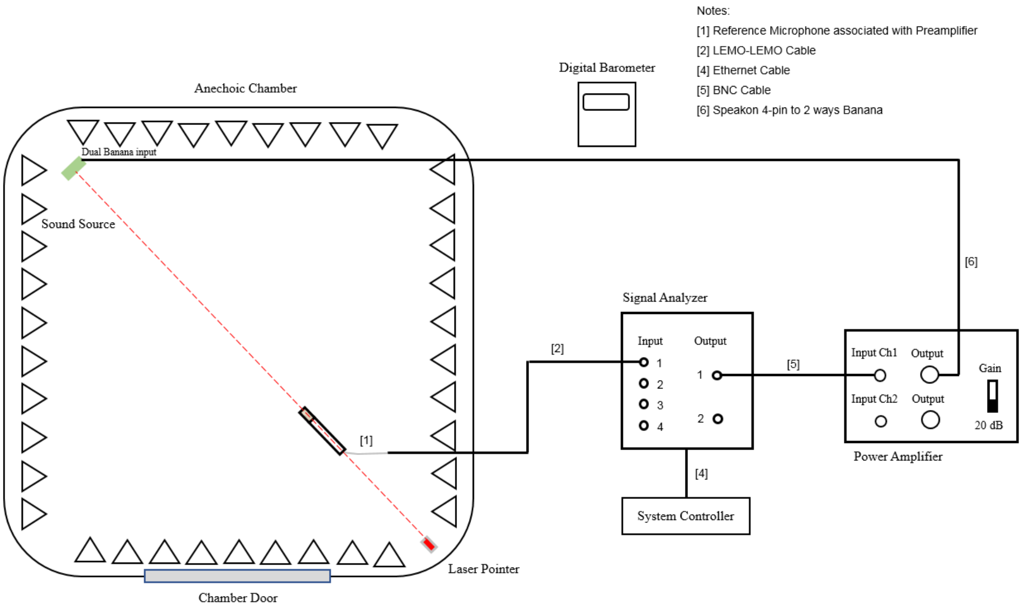

Figure 10a. *Connection diagram for measurement of the acoustic pressure generated by the sound source at the HRP in a free sound field*

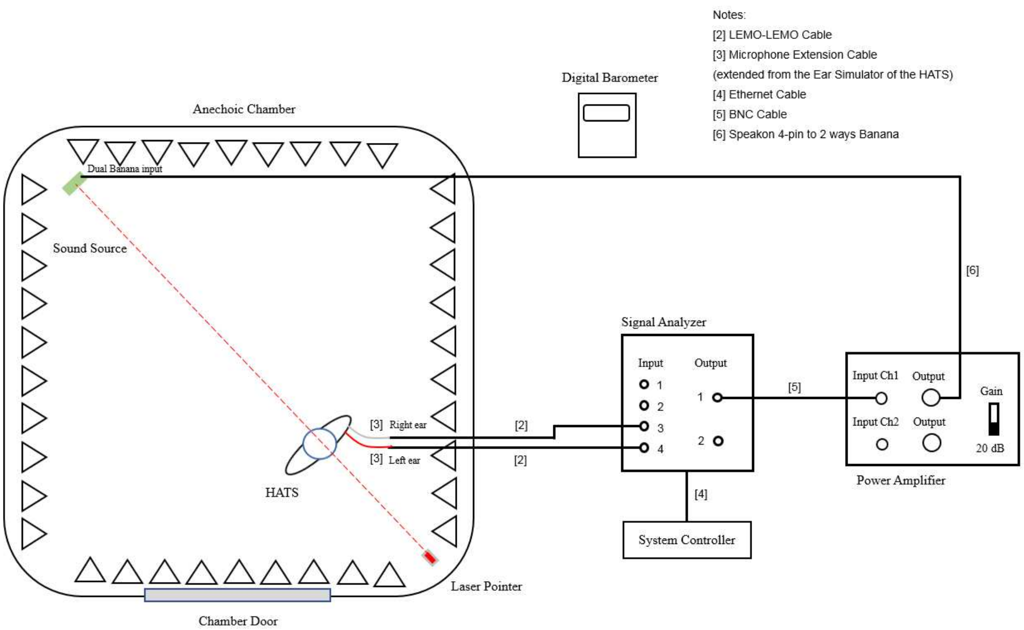

Figure 10b. *Connection diagram for measurement of the acoustic pressure at the DRP of the HATS*

The uncertainty components for calibration of the sound pick-up free-field frequency response of the HATS include: service uncertainties of the reference microphone, the pistonphone and the signal analyzer, uncertainties due to the discrimination error of the HATS ears calibration system, repeatability of measurements, environmental conditions as well as the misalignment of the reference microphone and the HATS at the HRP. These uncertainties are either obtained from our calibration reports or evaluated experimentally.

The dominant uncertainty component is the measurement uncertainty due to the misalignment of the HATS at the HRP. Due to the limited space of the anechoic chamber, the calibration covers an extensive range from 315 Hz to 8 kHz and the best measurement uncertainty is 1.4 dB.

4. CALIBRATION RESULTS

The maximum deliverable sound pressure level and the harmonic distortions of the HATS mouth and the sound pick-up free-field frequency responses of the HATS were calibrated by the HATS talker and ears calibration systems in our laboratory and the measurement results are as follows:

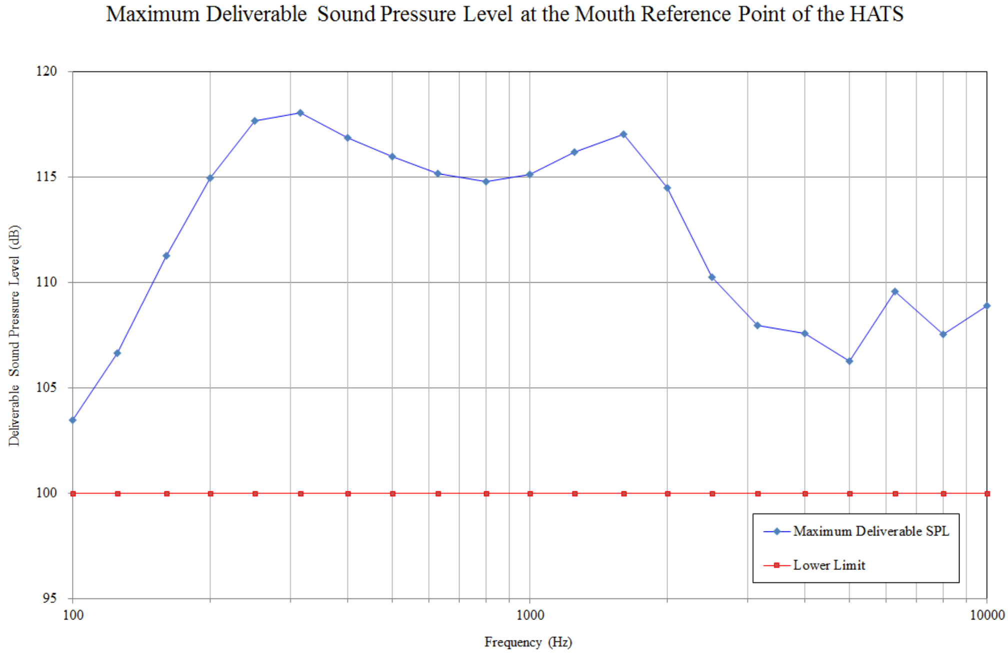

Figure 11a. *Calibration result of the maximum deliverable sound pressure level of the HATS mouth*

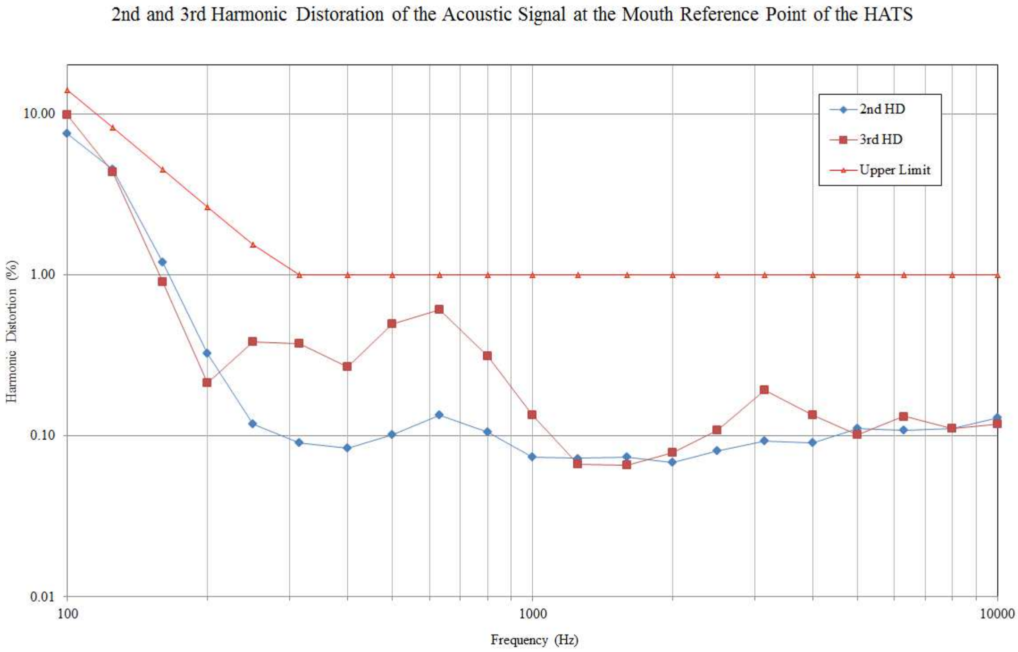

Figure 11b. *Calibration result of the harmonic distortions of the HATS mouth*

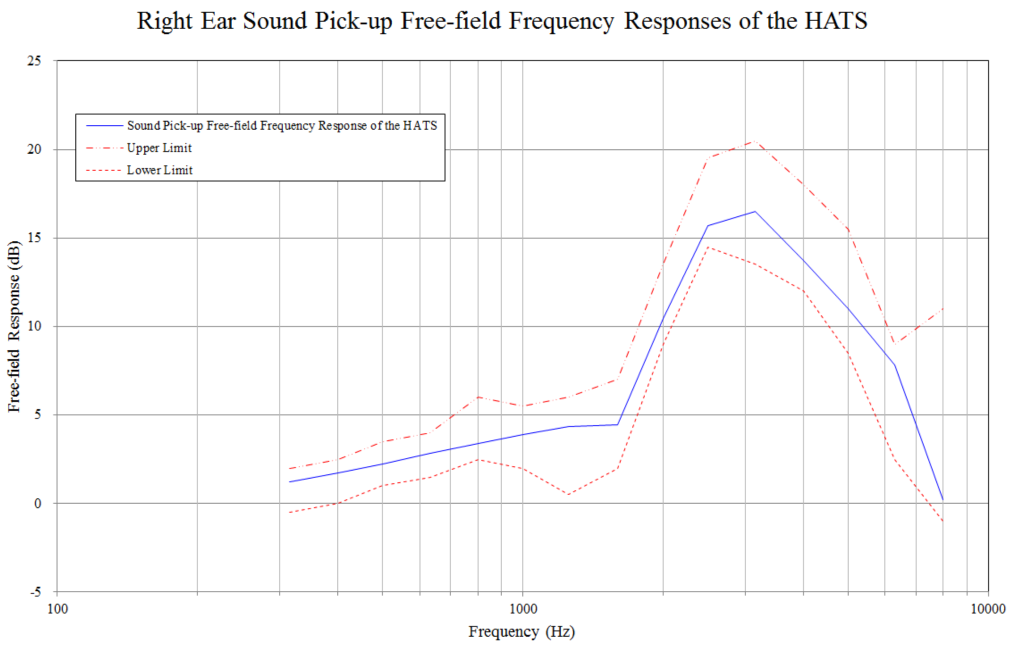

Figure 11c. *Calibration result of the sound pick-up free-field frequency response of the right ear of the HATS*

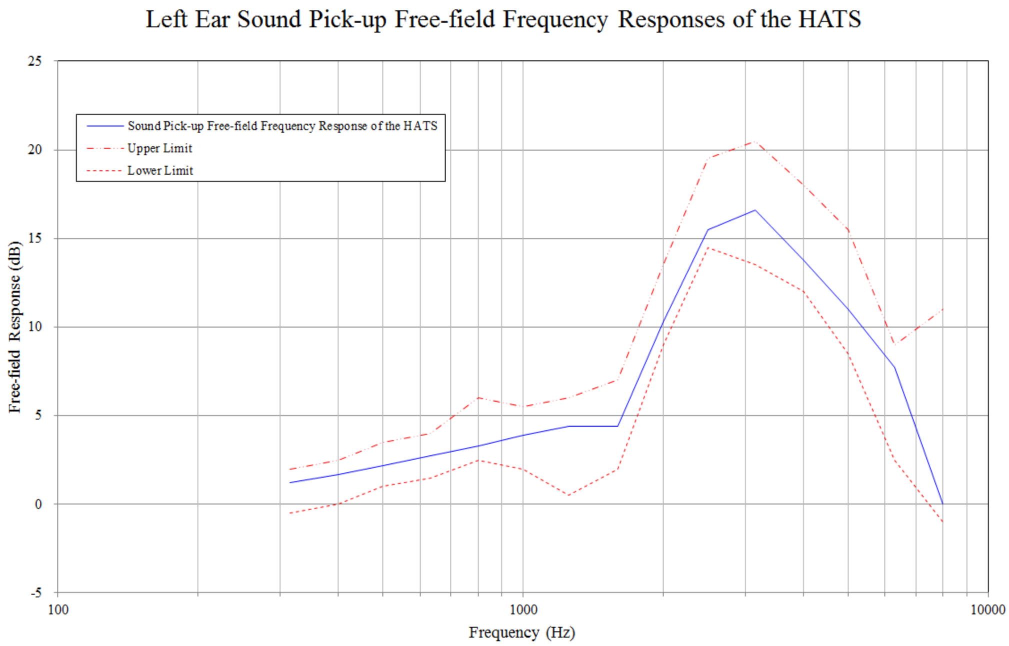

Figure 11d. *Calibration result of the sound pick-up free-field frequency response of the left ear of the HATS*

5. CONCLUSIONS

A description is given of an elaborated HATS calibration system for calibration of the sound emissions and sound pick-up characteristics of HATS in accordance with the Recommendation ITU-T P.58 (05/2013). The system comprises a personal computer with control software, a free-field reference microphone, a pressure-field reference microphone, a pistonphone, a barometer, a sound source with a power amplifier and a signal analyzer. All the measurements are conducted in the laboratory's anechoic chamber. The calibration range for sound emission parameters is from 100 Hz to 10 kHz while the range for sound pick-up free-field frequency response is from 315 Hz to 8 kHz. Further study will be pursued to extend the measurement range down to 100 Hz. The best measurement uncertainties of the three measurands (maximum deliverable sound pressure level, harmonic distortions and sound pick-up free-field frequency response) of the HATS calibration system are 0.5 dB, 1.5 % and 1.5 dB respectively.

6. REFERENCES

1. *ITU-T Recommendation P.58 (05/2013) "Head and torso simulator for telephonometry" Series P: Terminals and subjective and objective assessment methods. Objective measuring apparatus (Geneva, Telecommunication standardization sector of ITU-T).*

2. *ITU-T Recommendation P.57 (12/2011) "Artificial ears" Series P: Telephone transmission quality, telephone installations, local line networks. Objective measuring apparatus (Geneva, Telecommunication standardization sector of ITU-T).*

3. *IEC 60318-4 Ed. 1.0 (2010) "Simulators of human head and ear – Part 4: Occluded-ear simulator for the measurement of earphones coupled to the ear by means of ear inserts" (Geneva, Electrotechnical Commission).*

4. *JCGM 100:2008 "Evaluation of Measurement Data – Guide to the Expression of Uncertainty in Measurement", (Joint Committee for Guides in Metrology).*

5. *HATS Calibration WT-9944 (10/2017), published by Brüel & Kjær*.

6. *B&K PULSE Labshop - An Introduction to PULSE (09/2003), published by Brüel & Kjær*.