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A Headphone Measurement System Covers both Audible Frequency and beyond 20 kHz (Part 3)

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ABSTRACT

New headphone frequency response measuring scheme was standardized as JEITA RC-8140B-1 in March 2016. The basic idea of the scheme is that the frequency response is to be measured by HATS and compensated by a free-field HRTF of HATS used in the measurement.

One of the advantage of this measuring scheme is obtained results has equivalent implication with the results of free-field frequency response of the loudspeakers.

This report supplement the previous report which proposed basic idea of above said scheme by adding topics regarding newly developed HATS to improve signal to noise ratio in high frequency area above 20 kHz with ear simulators.

1 Introduction

Growing supply of Hi-Res (Wider frequency / dynamic range by higher sampling rate / quantization bit) digital audio sources were led by popularization of internet contents downloading or streaming. This also led higher demand for Hi-Res capable audio equipment throughout the industry. Japanese audio manufacturer's alliance, "Japan Audio Society (JAS)" offered criteria for their "Hi-Res" icon program and this icon became the sign of "good quality audio equipment" now.

The headphones are one of the most vital driving forces to the industry. JAS also stated its criteria as "High frequency requirement of the Rated Frequency Response" is 40 kHz or above.

In loudspeaker area, above criteria is based on standard measuring system described in IEC 60268-5. However in the area of headphones, there were no standard for frequency measurement scheme above 20 kHz which loudspeakers have. To solve this issue, Japanese standardization organization JEITA published a new standard for headphone frequency response measurement in March 2016.[1] This standard is based on ideas of using frequency response measured by HATS conformable with IEC 60318-7 and free field compensation using the HRTFs of said HATS. (Figure1)

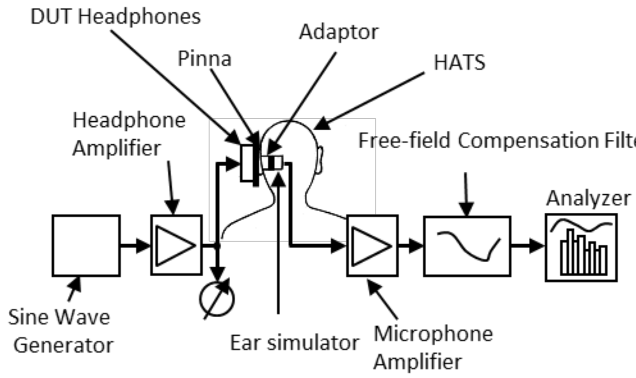

Figure 1. RC8140B-1 Measurement System.[1]

This standard measuring method enabled to evaluate measurement result regardless of microphone frequency result by comparing headphone response and individual HRTF of HATS used in the measurement. This also enabled to compare the result directly with those of loudspeaker response in free-field environment. Thus now, above new standard is cited by Japan Audio Society (JAS : Japanese audio manufacturer's association) as a standard measurement scheme to judge whether the products are good to label with "Hi-Res Icon" or not.

The purpose of this series of study is to establish practical measurement system to cover entire frequency from below 20Hz to 100 kHz or more. In a series of our past reports, studies for the HATS including our own prototype (Prototype 1) and standard one and technical tips for methodology for free field compensation for high repeatability were shown.[2] Then a conclusion is inducted as a combination of Standard HATS and ISO R10 frequency points (=1/3 Octave, Averaged from R160 : 1/48 Octave response) free-field compensation filtering were proposed as a practical solution to obtain good reproducibility.[3]

However, above solution using conventional standard HATS has some difficulty on measuring headphones and also HRTF for free field compensation due to its low signal to noise ratio in high frequency area. Sometimes it needs 100 mW of input to headphone for frequency response and 10 watts of input power to loudspeaker for HRTF measurement which are extremely high and far away from normal listening level. This was coming from microphone used on the standard HATS were using 1/2" capsule [4,5,6] which has low sensitivity in high frequency area.

To solve above issue, new HATS was designed and constructed.

In this report, below items are to be reported.

a) HATS construction: Introduction of new HATS prototype (Prototype 2) with higher sensitivity and better signal to noise ratio in high frequency area. The HATS comes with ear simulators and 1/4" microphones instead of 1/2" or 1/8" microphones.

b) Examples of measured results using above system.

Also in discussion part, simulation result of sound pressure distribution in ear canal will be reported and the advantages of 1/4" microphone application to HATS are also to be shown.

2 New HATS Concept

Based on past discussion, newly developed HATS were designed as to accommodate below conditions.

- Implementation of ear simulators.
- Use of 1/4 inch microphone.

Figure 2. HATS Prototype 2

HATS Prototype 2 shares most parts with current existing industrial standard HATS but has different ear simulator.

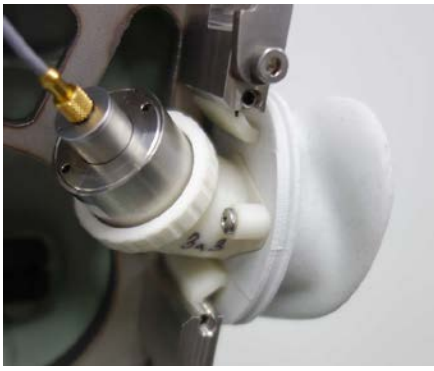

Figure 3. Ear Simulators

Ear Simulator is located around the 1/4 inch microphone and its acoustic impedance is set to follow IEC 60318-4.

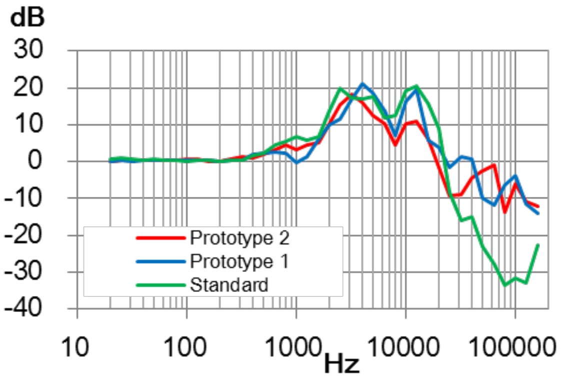

Figure 4. Measured HRTF

3 Measured Results by Newly Developed HATS

3.1 Test System

Figure 5 shows actual system used to test the new HATS. With this system, free-field compensation calculation was done manually by using Microsoft Excel spread sheets.

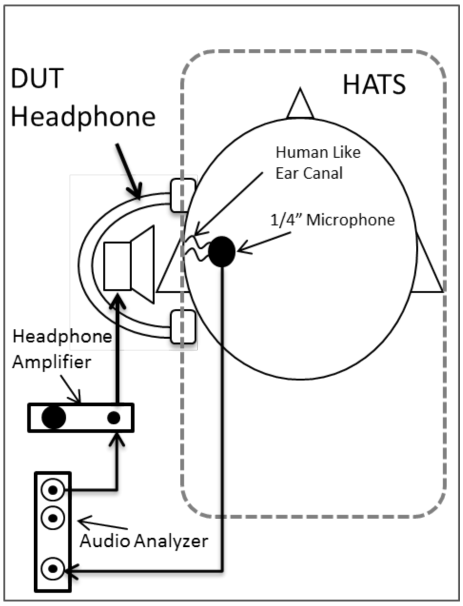

Figure 5. Measurement system block diagram

3.2 Measured Results by the System

Here are measured results of several different types of headphones: Circum-aural type, Supra-aural type and Insert type headphones. All the headphones were measured at 1mW input to driver unit. 1mW was chosen as to represent normal listening level by the consumers.

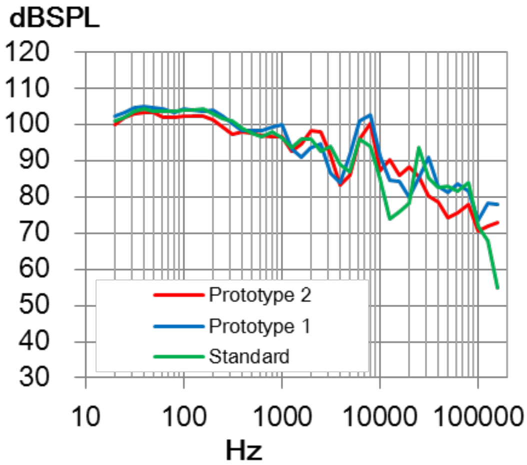

Figure 6. Measured Results
Circum-Aural Type Headphones on different HATS

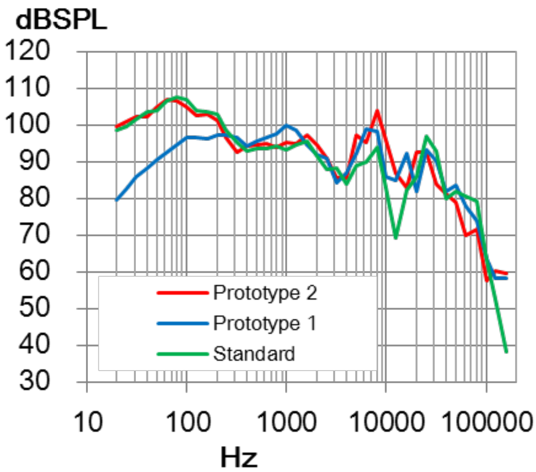

Figure 7. Measured Results
Supra-Aural Type Headphones on different HATS

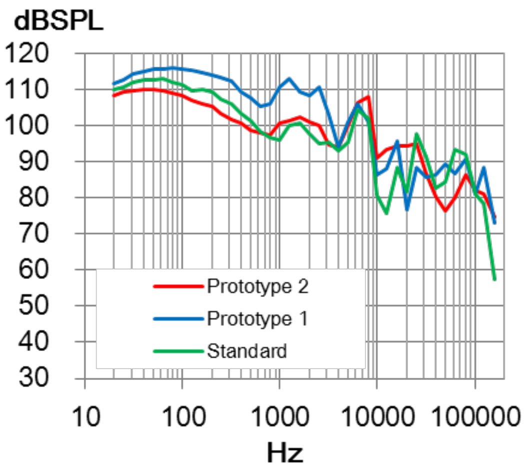

Figure 8. Measured Results
Insert Type Headphones on different HATS

Figure 6 to 8 shows measured results for circum-aural headphones, supra-aural headphones and insert type headphones.

These result shows HATS Prototype 2 shows best probability among three HATS.

They show similar frequency response on three different HATS except low frequency area on supra-aural headphone measurement on Prototype 1. (Figure 7) This difference was from air leakage caused by bad fitting between its hard ear pinna and the headphones. This was improved in prototype 2 by applying soft pinna.

Figure 8 shows measured results of insert type headphones.

Prototype 1 shows higher response in area of 20 Hz to 4 kHz due to lack of ear simulator. This problem is discussed in previous report.[3]

Industry standard HATS shows almost identical response with new HATS however output in high frequency area is very low in comparison with other HATS and close to background noise level. (Figure 9-11)

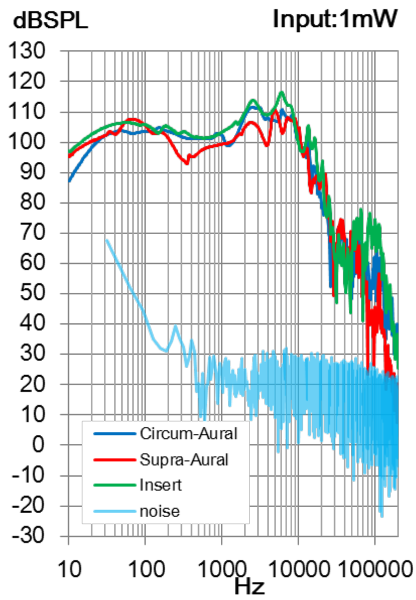

Figure 9. HATS output vs. background noise spectrum Instant Value:
HATS Prototype 2

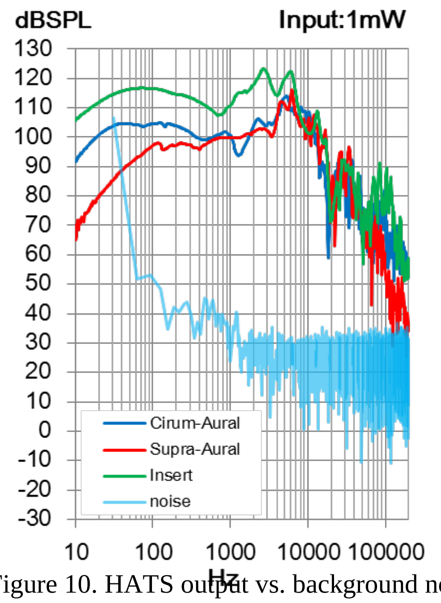

Figure 10. HATS output vs. background noise spectrum: Instant Value : HATS Prototype 1

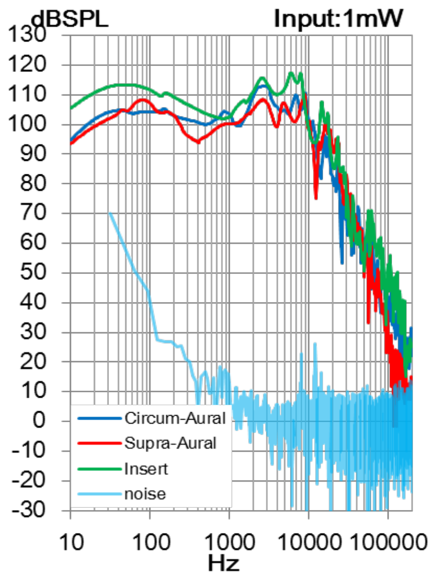

Figure 11. HATS output vs. background noise spectrum: Instant Value: Industry Standard HATS

3.3 TIPS for Better Measured Results

To obtain good results on the frequency response measurement in high frequency area, signal to noise ratio at the measurement environment must be considered carefully. To obtain good enough probability of +/- 1dB, signal to noise ratio must be at least 10 dB or more in instant value.

In case of measurement result shown in Fig.9, Supra-aural headphones measurement do not have good signal to noise ration of 10dB. Increase of electrical input to the headphones helps to obtain good signal to noise ratio. (Figure 12)

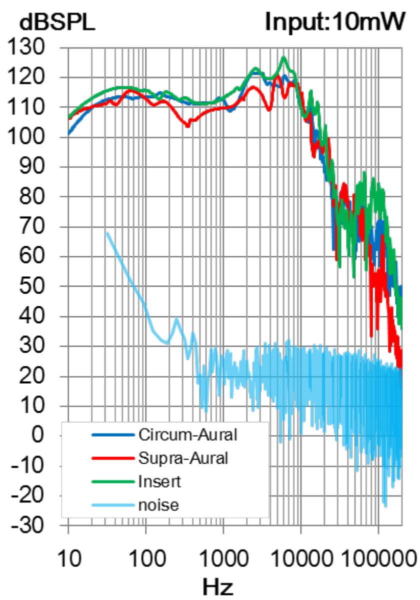

Figure 12. HATS output vs. background noise spectrum: Instant Value: HATS Prototype 2

4 Discussion

As touched in previous section, choice of microphone used in HATS is very important to obtain good measurement results in a point of view of signal to noise ratio.

However there is one more question that the microphone mechanical-acoustic construction does represent that of human body.

A series of simulation of steady state SPL distribution in human ear canal was done to figure out this question. Ear canal shape was from an individual and taken by MRI. (Figure 13 to 17) All the figure are rear view of left ear canal.

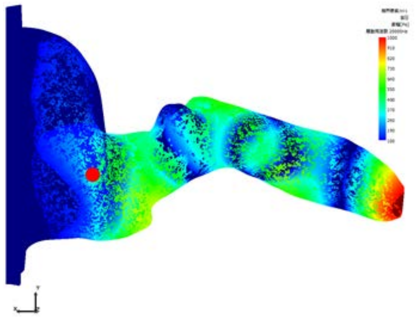

Figure 13. SPL Simulation inside of human ear canal: (20 kHz)

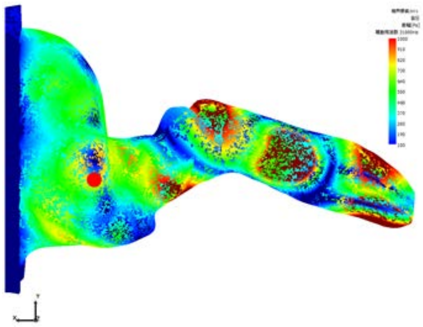

Figure 14. SPL Simulation inside of human ear canal: (31 kHz)

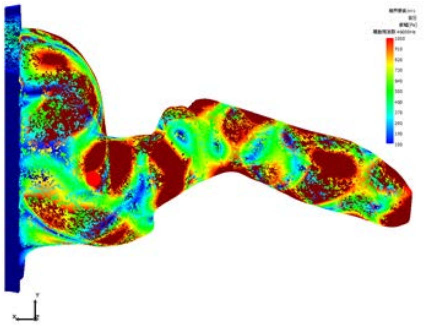

Figure 15. SPL Simulation inside of human ear canal: (46 kHz)

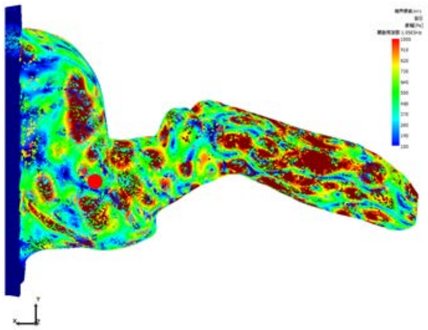

Figure 16. SPL Simulation inside of human ear canal: (105 kHz)

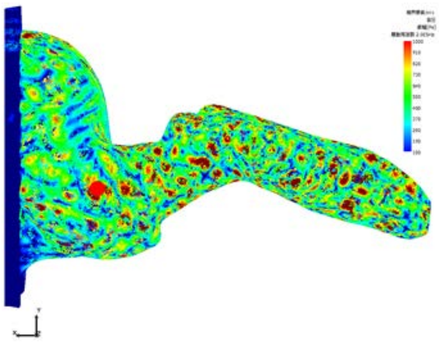

Figure 17. SPL Simulation inside of human ear canal: (200 kHz)

At the point of 20 kHz, entire SPL distribution shows single dimensioned behaviour. However above approximately 30 kHz, distribution mode transfers into 3- dimensional mode. In this area, sound pressure level on ear drum is not even on ear drum surface and the average sound pressure level of ear drum is given as an ear drum area wide integral value of this local SPL distribution. From this point of view, the size of microphone membrane should be considered as to follow the size of human ear drums.

From the observation, 1/4 inch microphone is best or best compromise among the current existing standard microphones.

5 Conclusions

- HATS with ear simulators and 1/4 inch microphone with real human ear canal shape showed a good performance in measuring all type of headphones including circum-aural, supra-aural and insert type headphones' frequency response using measuring method specified by JEITA RC-8140B-1 standard.

- Application of 1/4 microphone to HATS is the best or best compromise when taking distribution of sound pressure level inside of ear canal into account because size of membrane of said microphones are close to human ear drum.

6 Acknowledgement

This work was supported by many of our company colleagues who dedicated their time for designing HATS and also for their great efforts using specialties in computer simulation to identify SPL distribution inside of ear canal.

References

[1] JEITA RC-8140B-1 (2016)

[2] N. Tsunoda et al., A Headphone Measurement System For Audible Frequency and Beyond 20kHz., AES Paper 9375; AES Convention 139; October 2015

[3] N. Tsunoda et al., A Headphone Measurement System For Audible Frequency and Beyond 20kHz., AES Paper 9530; AES Convention 140; June 2016

[4] Product Data Sheet, Head and Torso Simulator, Type 4128-C, Bruel & Kjaer (2014-10)

[5] IEC 60318-7 (2011)

[6] IEC 60318-4 (2010)