Auditory evaluation of very-high-frequency sounds radiated from the Japanese trains

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ABSTRACT

The purpose of this research is to clarify the state of hearing high frequency sound and to ensure safety and consideration for young people including children. In this study, we measured the hearing threshold of high frequency pure tone for 4 college students aged 21 to 24 and high frequency sound in the train together with conducting demonstration experiment and auditory sensation. From the measurement results of the high frequency pure tone audible range, we could confirm everyone in the 4 people was able to list up to 16 kHz and 3 out of 4 people were able to listen up to 22 kHz although there were individual differences in the threshold value. Moreover, during the demonstration experiment and the auditory experiment in the train we could confirm that some people feel uncomfortable after hearing the high frequency sound. This time there were four participants in the experiment, but this number was sufficient to clarify the exposure condition of high frequency sound and its influence became clear in everyday life.

Keywords: High frequency noise, Environment, Annoyance, Hearing threshold, Train noise
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1. INTRODUCTION

In recent years the high frequency sound has been widely applied at various industries in our everyday life such as sensors, medical equipment, welding etc. and the number of occasions when people are exposed to high frequency without knowing is increasing. The products including the high frequency components do not use high frequency as it is, but several products intentionally generate it. As an example, there are mouse and stray cat repellers, or moreover repellers of young people hanging around in the downtown. These are high-frequency sounds with a sound pressure level exceeding 100 dB [1]. They use high frequency sounds around 18 kHz to 22 kHz, or higher, and in most cases such devices are designed with consideration for the human audible range (20 Hz to 20 kHz). Also, it has been reported that high-level high-frequency sound is included in railway noise [2], [3]. In some cases, it is possible to identify the source, but recent studies have revealed that high-frequency sounds with sound pressure levels exceeding 80 dB are often observed even in urban environments with a wide variety of sounds mixed [1, 4].

On the other hand, among systematic studies on the effects of high frequency sound exposure on living organisms there are few researches on exposure studies and measurement methods for high frequency sounds, however the researches on hearing of high frequency sound has been conducted by several research groups. The target auditory of such studies is the university students and adults, and almost no reliable data on hearing targeted on young auditory has been reported. However, in the study by Ueda et al. [4], we conducted experiments for children and young people, and found the audible sound for all of eight children participating was up to 22 kHz, while all young people could listen up to 16 kHz. Furthermore, we draw the conclusion, the higher the frequency is, the more it feels "noisy" or "uncomfortable". Basing on these results, we concluded that it is necessary to consider whether enough safety and consideration for high frequency sound exposure to young people including children as well as adults in daily life is taken.

Therefore, in this research, we aimed at obtaining data with higher reproducibility by conducting experiments with people with higher listening ability of high-frequency sounds basing on the listening experience of train running sound which was taken at the Hiroe's research. For this reason, the author conducted the experiments concerning hearing of high-frequency sound in the moving train at first, and after that, similar listening was conducted for 4 university students from 21 to 24 who measured the high frequency audible range in the soundproof room. By conducting such experiments, we investigated the actual condition of high frequency sound exposure in the train.

2. MESURMENT OF SOUND FIELD

2.1 Outline of preliminary measurements

At first, in order to clarify the generation status of high frequency sound in the train, we actually took the train and carried out actual measurement. Before the survey, we confirmed whether author can hear the high frequency sound by using the measuring application on smartphone. It turned out, that high frequency sound of 18 kHz can be heard.

Surveyed was the section between Hon-Atsugi and Ebina stations on the Odakyu Odawara line on both up and down lines. The survey period was three days from September 25 to 27, 2018, and a total of 20 surveys were conducted. We targeted on 3 kinds of trains – local, express and rapid express. The survey method was confirmation by the author own ears and the record of the running sound observed in the train. For the measurements inside the train, we used a compact, inconspicuous PCM recorder (KENWOOD, MGR-E8) and recorded the in-vehicle sound with a sampling frequency of 96 kHz and Z (flat) characteristics. The survey was conducted twice - the primary and the secondary survey. Fig. 1 shows the target sections of the first and second surveys. In the primary survey section surrounded by the red continuous line in the figure, there are two curved tracks (A, B in Fig. 1) and one railway bridge between Hon-Atsugi and Atsugi.

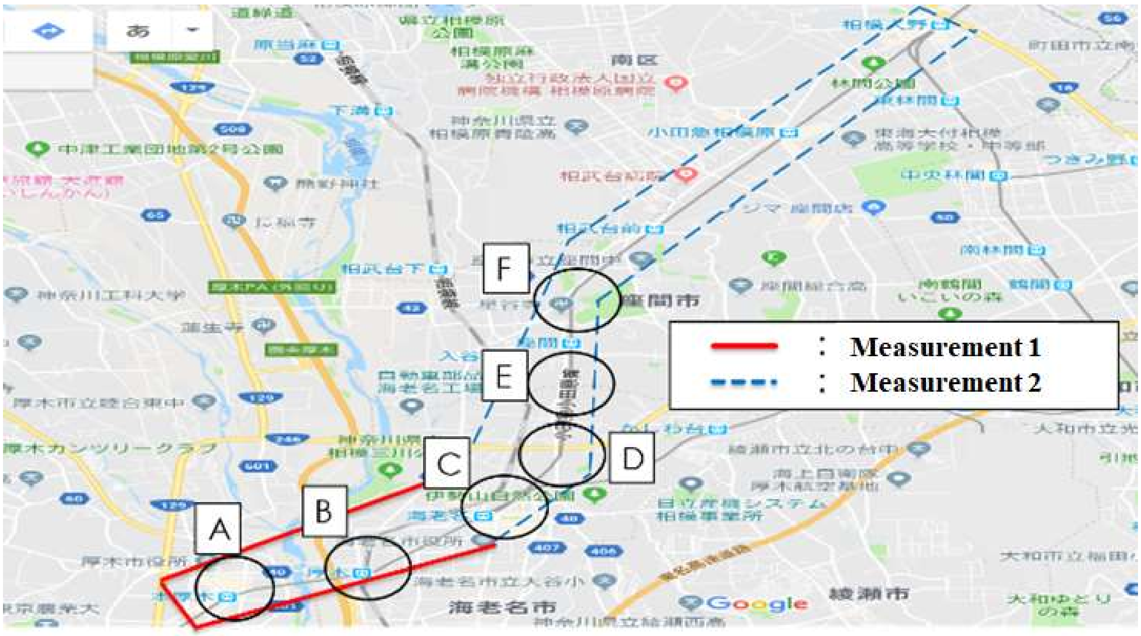

*Fig.1 ―Target section in survey 1 and 2 (Hon-Atsugi – Sagami-ono Stations up and down lines) * A to F in the figure indicate curved trajectories.*

2.2 Results of measurements

First, as a result of the first survey, a lot of high frequency sounds were confirmed in the curves around Atsugi station (A, B in FIG. 1). Furthermore, as a result of analyzing the recorded data, it was found that high frequency sounds in the vicinity of 35 kHz actually occurred from 20 kHz. Figures 2 and 3 show examples of analysis results. Next, the distribution of points where high-frequency sound was heard in survey 2 is shown in Fig.4.

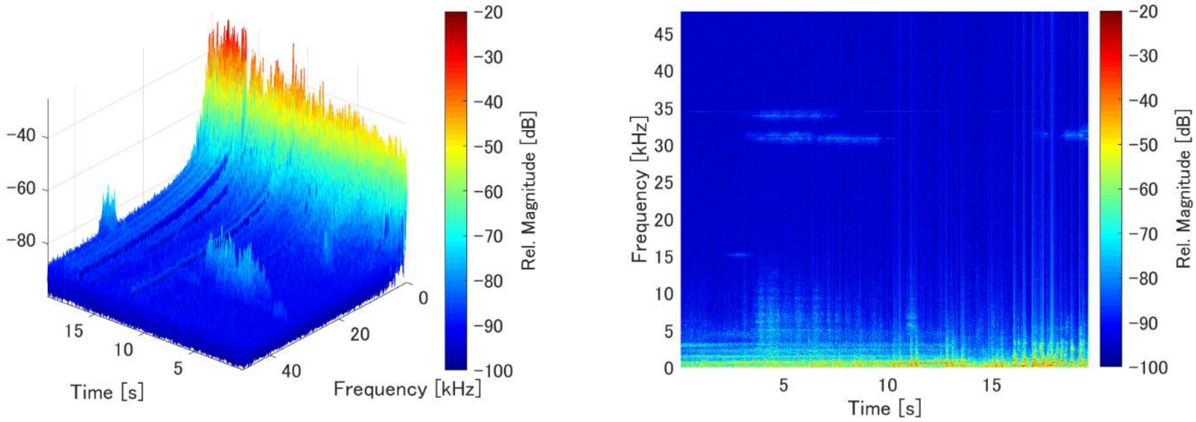

Fig. 2 ―FFT analysis result of survey 1 (A: Hon-Atsugi - Atsugi).

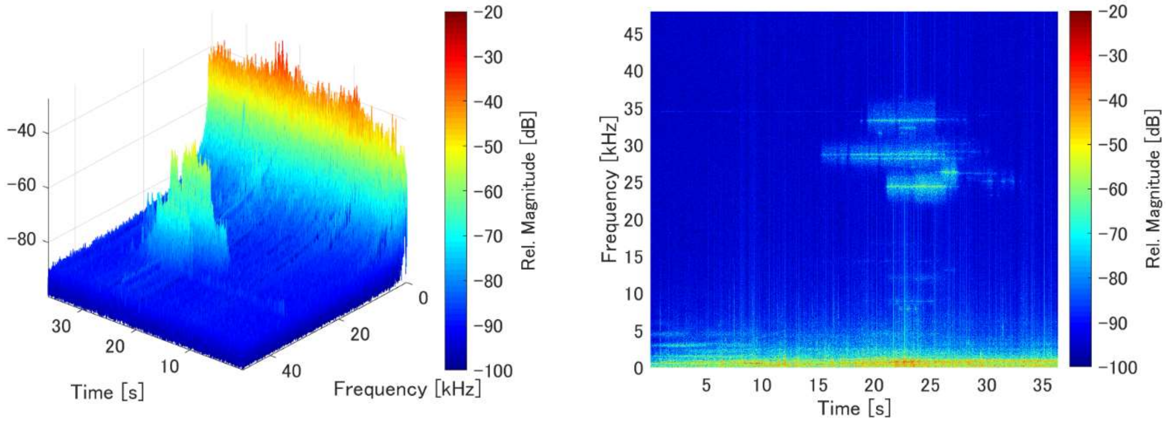

Fig. 3−FFT analysis result of survey 1 (B: Atsugi ~ Ebina).

Similarly to survey 1, although it was not possible to hear on the straight line, there were total of 6 curved tracks between Atsugi station and Sagami Ono station "Hon-Atsugi station" near (A), "Atsugi station" near (B), "Zama – Soubudai-mae" There are a total of 6 curved tracks of 1 place (F) and 3 places (C, D, E) between "Ebina station and Zama station". At five of the above station the high frequency sound was recorded with frequency of more than 10 times.

Fig.4−The place of occurrence between Atsugi station and Sagamiono station.

3. AUDITORY EVALUATION FOR COLLOGE STUDENTS

3.1 Outline of auditory experiments

In this auditory experiment, in order to verify whether the high frequency sound can be heard in the train or not, after checking the hearing threshold for the high-frequency sound in the soundproof room, we actually took a train and conducted a listening experiment as in the surveys 1 and 2.

3.2 Measurement of pure tone heating thresholds of high frequency sound

First, in order to confirm the degree of hearing of the high frequency sound of the experiment participants, the pure tone auditory threshold was measured in the soundproof room. There were 4 experiment participants (3 male, 1 female) from 21 to 24 years old. The test sound used for measuring the threshold was repeatedly presented at a cycle of once per second with a windowing (Hanning) with onset and offset for sinusoidal wave 200 ms and steady-state part 600 ms respectively. The frequency was tested on 11 sounds at 1 kHz, 2 kHz, 4 kHz, 8 kHz, 12 kHz, 14 kHz, 16 kHz, 18 kHz, 19 kHz, 20 kHz, 22 kHz in total. As shown in Fig. 5, it was reproduced from a speaker (YAMAHA, MSP 3) located 500 mm away from the front of the participant's face. To measure this pure tone hearing threshold, the limit method of ascending sequence was used. In the limit method, there are disadvantages that measured values are susceptible to cognitive bias such as prediction and beliefs, and constant method and adaptation method are often adopted to avoid this. However, on the other hand, the constant method and the adaptive method require dozens of operations to obtain one measurement value. Moreover, there is a disadvantage that the restraint time of the experiment participants is extended. For this time, we adopted the extreme method which can measure the threshold value in a short time. However, we tried to avoid the influence of cognitive bias etc. by inserting catch trial as appropriate.

In the threshold measurement, at first, the limit method of the ascending sequence which starts from a sufficiently low level which cannot be heard by experiment participants was used. The level increase per time is 3 dB, and the listener raises a signal once the inspection sound could be heard. The average of several times of the presentation level at this time was taken as the minimum audible range value.

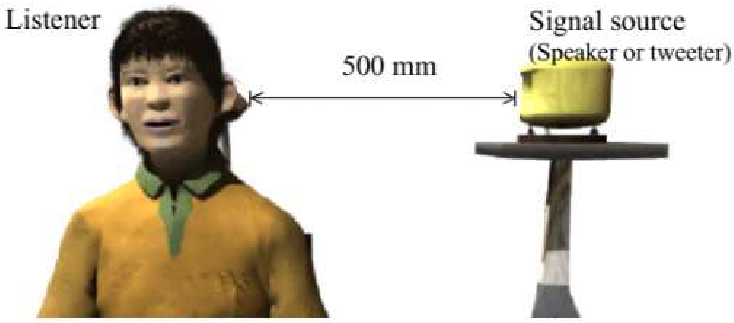

Fig.5 —Measurement of pure tone threshold of high frequency sound.

Table 1 shows the average of the measurement results of the high frequency pure tone thresholds for each experiment participant. Up to the frequency of 8 kHz, there was no big difference for 4 people, but a difference began to appear between 1 and 3 other people from 12 kHz, and significantly big difference was seen in 4 people over 16 kHz. Even if the experiment participants were almost the same age, there was a big difference in the audible range of the high frequency sound. It turned out that some people cannot hear if the high frequency sound is not at a high sound pressure level or someone cannot hear it even at a high sound pressure level.

Table 1 —Average of the measurement results of the high frequency pure tone thresholds for each experiment participant.

Frequency and Participants No.	1	2	3	4
1 kHz	22.1 dB	20.2 dB	20.2 dB	21.6 dB
2 kHz	23.6 dB	20.2 dB	20.2 dB	22.9 dB
4 kHz	20.2 dB	20.2 dB	20.2 dB	20.2 dB
8 kHz	24.7 dB	20.2 dB	20.2 dB	22.0 dB
12 kHz	33.2 dB	20.2 dB	20.2 dB	20.2 dB
14 kHz	29.3 dB	20.2 dB	20.2 dB	20.2 dB
16 kHz	41.3 dB	20.2 dB	35.0 dB	22.7 dB
18 kHz	65.8 dB	44.4 dB	—	30.8 dB
19 kHz	57.7 dB	43.7 dB	—	39.6 dB
20 kHz	63.9 dB	38.7 dB	—	35.1 dB
22 kHz	77.6 dB	42.6 dB	—	57.4 dB

* "-" indicates that measurement is impossible.

3.3 A field experiment

Next, the same experiment participants conducted a simple listening experiment in the running train to ascertain whether or not high frequency sound can be heard within the train.

Experiment participants, as in Section 2.1, got on the train in the interval between Atsugi station and Sagami-ono stations on the Odakyu Odawara line and checked the position of the train where the high frequency sound was heard with Google Maps with ● on the map handed in advance. In addition to answering whether it feels unpleasant high-frequency sound heard by ○ or x with a side.

The object of this auditory experiment was two types of express and local trains. This is because the highest auditory frequency of high frequency sounds is at express trains as it comes from the frequency on the local trains is the second most. Moreover, the number of times of stoppage and vehicle type are different from those of the other two models.

4. CONCLUSIONS

The purpose of this research is to clarify the state of hearing high frequency sound and to ensure safety and consideration for young people including children. In this study, we measured the hearing threshold of high frequency pure tone for 4 college students aged 21 to 24 and high frequency sound in the train traveling on the Odakyu Odawara Line together with conducting demonstration experiment and auditory sensation.
From the measurement results of the high frequency pure tone audible range, we could confirm everyone in the 4 people was able to list up to 16 kHz and 3 out of 4 people were able to listen up to 22 kHz although there were individual differences in the threshold value. Moreover, during the field experiment and the auditory experiment in the train we could confirm that some people feel uncomfortable after hearing the high frequency sound. This time there were four participants in the experiment, but this number was sufficient to clarify the exposure condition of high frequency sound and its influence became clear in everyday life.

We will continue to increase the number of participants in the experiment and clarify the influence on human exposure to high frequency sound exposure.

5. REFERENCES

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