Investigation on VHF sounds in the ears project Japan – part3

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ABSTRACT

We have reported the recent activities for research on very-high-frequency (VHF) sound in Japan. In this paper (part-), we introduce the background, summary of our investigation and the result of subjective hearing threshold in such VHF region. The issues on high pressure of VHF sounds including ultra sounds in air that cause various subjective effects have become important around all world. Similar problems on VHF sounds, for example, noise annoyance by VHF sounds radiated from rodent repelling devices, were emerging also since about 10 years ago in Japan. The ears project Japan which have been established against such issues in recent years decided to conduct VHF research, measurement and evaluation in Japan.

We introduce summary of the ears project Japan and measured results of subjective threshold in VHF region positioned as part of most important research issue.

INTRODUCTION

First, we define very-high-frequency (VHF) sound as the sound in the 16 kHz to 32 kHz range which some people can detect. In recent years, the issues on high pressure of VHF sounds including ultra sounds in air that causes various subjective effects have become important around all world [1] -[7]. These devices which utilize or generate VHF sounds as like pest control devices, ultrasonic cleaning machines and IH cookers are increasing in public space or our living environment in Japan. Policymakers need guidelines from which to work for VHF sound. Guidelines must be based on good evidence. Evidence must be collected with reliable measurement methods and calibrations, and this is unlikely to be possible by simply extending to the ultrasonic regime the established procedures used in audiology, acoustical engineering, and metrology at audio frequencies. There must be a sufficient volume of evidence to be statistically significant, and it must not ignore possible variations in sensitivity seen in the population, and between and within subsets of the population. The issues on high pressure of VHF sounds including ultra sounds in air that cause various subjective effects have become important around all world. Similar problems on VHF sounds, for example, noise annoyance by VHF sounds radiated from rodent repelling devices, were emerging also since about 10 years ago in Japan. The ears project Japan which have been established against such issues in recent years decided to conduct VHF research, measurement and evaluation in Japan. This paper, we introduce summary of the ears project Japan and measured results of subjective threshold in VHF region positioned as part of most important research issue.

EARS PROJECT JAPAN

We also started a project in Japan with reference to the ears project and ears project II [8] that the EU has been doing mainly. The ears project Japan which have been established against such issues in recent years decided to conduct VHF research, measurement and evaluation in Japan since 2019. This project concerns two aspects of hearing assessment (evaluation and conservation) and acoustic measurement [9].

Objectives

The objective of this project is the improvement and further development of strategies and methods of metrology and calibration for hearing assessment, hearing diagnosis and safety.

The specific objectives of the project are:

1. The VHF sounds measurement;
2. Measurement of hearing threshold on VHF sounds;
3. Auditory evaluations on VHF sounds;
4. Physiological measurement by EEG and ABR;
5. Holding workshops on measurement methods;
6. Others

and to create the knowledge for future guidelines and policy framework to enhance the wellbeing of citizens and protect them from health hazards associated with infrasound and ultrasound.

Organization and Secretary members

This project is a member of the Institute of Noise Control Engineering of Japan (Figure 1). This project no institute could address all of these challenges on their own. In teamwork, this project, through coordination of national and individual activities into coherent research activities, will make a significant step forward to improve the metrology underpinning hearing assessment and audiological measurement. This project covers a wide range of audiology research and development. Physiological knowledge about the ear, acoustics engineering, and ultrasound, doctor of otorhinolarynoglogy and etcare combined.

Funding

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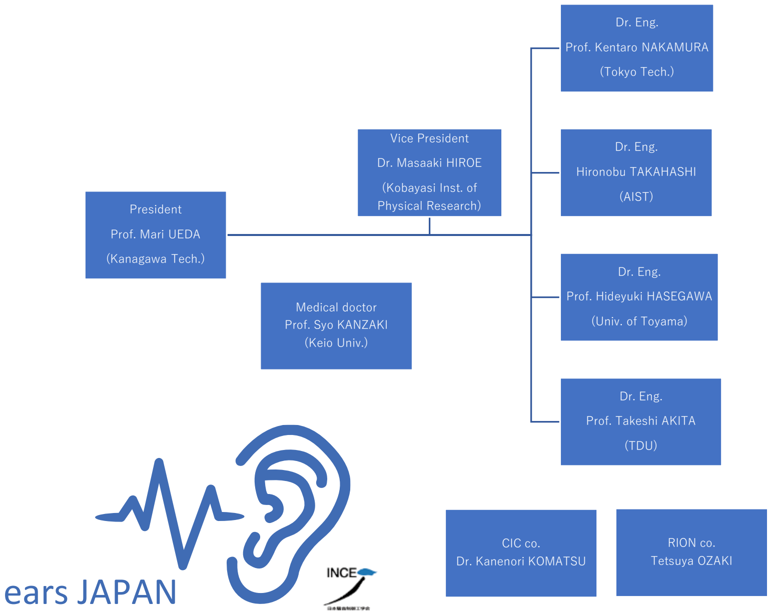


Figure 1: Organization chart of the ears JAPAN.

PURE-TONE HEARING THRESHOLD ON VHF SOUND

Example of the hearing threshold on VHF sound, two or more trials were conducted at each frequency, and the average of measured values was determined as the threshold[10]. Furthermore, any measured value that exceeded a sound-pressure level of 90 dB even once was scaled out. As described above, measured values using the method of limits are strongly influenced by cognitive bias. Therefore, to determine whether or not a participant's response was reliable, catch trials were used. A catch trial is the same as an ordinary trial, except no sound stimuli are presented. Therefore, when participants respond based on their predictions and beliefs, their responses also appear during catch trials. In this study, some participants made such responses during catch trials. Data of these participants were discarded, due to their low reliability.

Figure 2 presents the thresholds of 21 participants (including seven female participants); four were judged to be unreliable and were excluded. These participants were grouped as follows: ages 6 to 8 (five participants), ages 9 to 11 (nine participants), and ages 12 to 15 (seven participants). Here, × indicates the thresholds of the male participants, and ○ indicates those of the female participants. The solid line in the figure represents the threshold of a healthy person who hears a pure tone in a free-sound field, as specified in ISO 389-7.

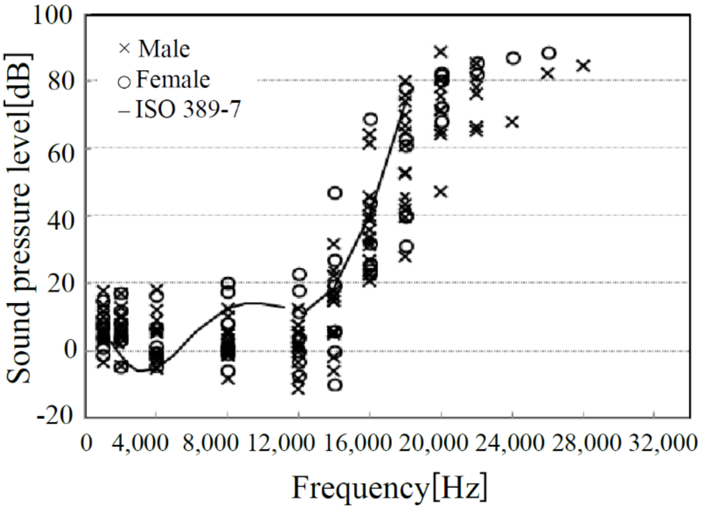


Figure 2: Example of children's hearing threshold.

During the test in this study, thresholds of all participants could be measured at frequencies of 18 kHz or less. At 20 kHz, the thresholds of eight participants were scaled out. Although the thresholds at 2 kHz and 4 kHz are higher than the values indicated in ISO, the thresholds of many participants were less than the values of ISO at frequencies above 12 kHz.

Thresholds at 2 kHz and 4 kHz may have been higher than the values in ISO because the measurement environment for this test is a soundproof room, where the background noise level is higher than in a free sound field (anechoic room). In other words, the lower limit of the measured value may be governed by the background noise level of the room. Furthermore, the background noise level seemed to be higher when the participant entered the room accompanied by his or her parent. Indeed, one participant expressed dislike regarding the presence of a parent, saying “Myself alone is better; another person is noisy.”

A speaker as the sound source was placed in front of the participant at a distance of 1m or more for measuring the threshold indicated in ISO. However, the sound source in this test was installed to the left of the participant 500 mm from the ear to secure a sufficient sound pressure level of 90 dB or above at the hearing position. When the sound source is placed in front of the participant, sound is heard by both ears; however, during this test, it can be assumed that the threshold measured was that of the left ear in most cases. The threshold decreases by several decibels when sound stimuli are heard by both ears, compared to that when stimuli are heard by a single ear8. Participants were instructed not to move the head if possible during measurement of thresholds; however, no headrest or other support was used. Therefore, the position and direction of the heads of some participants fluctuated greatly during the measurement. These factors are assumed to have made the measured value higher than the actual threshold. Thresholds lower than the values of ISO were observed in many cases in the high-frequency band over 12 kHz, in spite of these negative factors; this result indicates the hearing thresholds of children are lower than those of adults in the high-frequency band. While the threshold at 18 kHz indicated in ISO is a sound pressure level of 73.2 dB, only four of the twenty-one cases in this study exceeded this value, even when the highest threshold recorded was 80.2dB. However, the lowest threshold recorded was 28.2 dB, which was 45 dB lower than the ISO value. The average of the participants was 55.0 dB, which was 18 dB lower than the ISO value. Even at 20 kHz, which is commonly assumed to be the upper limit of audible frequency, the threshold was less than the sound pressure level of 80 dB in half of the total cases, with seven participants scaled out.

EXAMPLES OF THE VHF SOUNDS MEASUREMENT

Public space

The first group measured VHF sounds radiated from Underground shopping mall at the station.

Example of a measurement results [11] showed of the pest control device in the station that the maximum sound pressure level was about 120 dB directly under the device, and more than 90 dB at the point of 15 m away from the device (Figure 3). Furthermore, concerning the result of the questionnaire survey, the young people recognized the VHF sound from the pest control device more clearly when compared with the elderly people. Furthermore, most of the answerers who recognized the VHF sound reported negative evaluation, such as unpleasant, noisy, having a headache or an earache and so on.

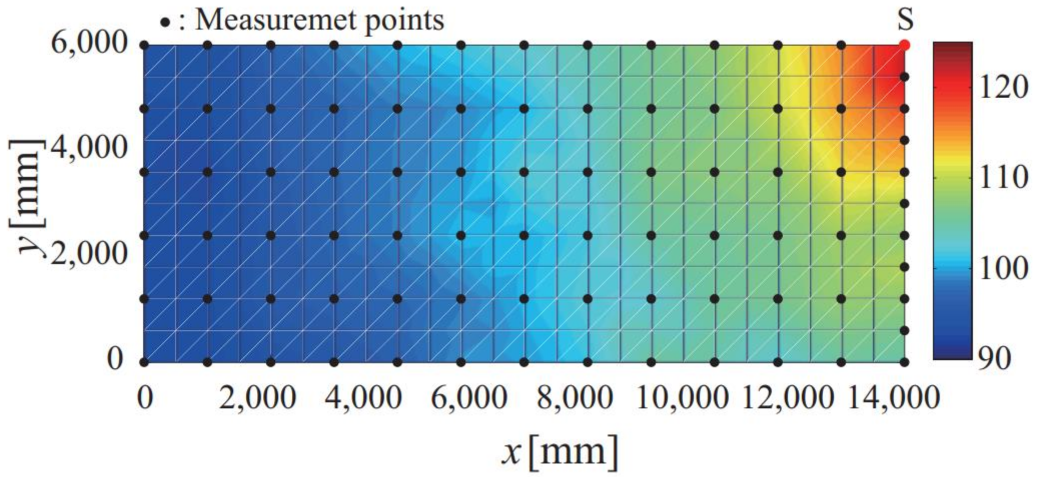


Figure 3: Sound pressure distribution by the pest control device is shown.

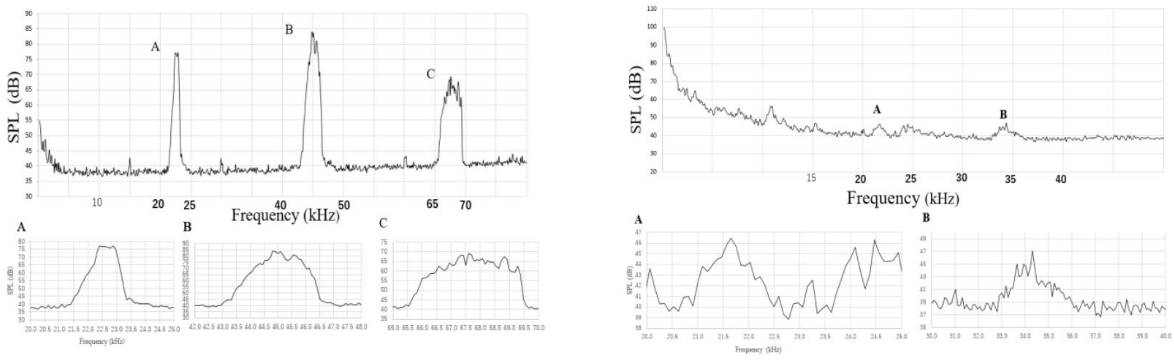
Measurements were made 1,500 mm above the ground with a WS3 microphone (BK, Type4939), and the results were recorded on a data recorder (NF, EZ7510) via a microphone adapter (BK, UA0035), pre-amplifier (BK,Type 2673), and conditioning amplifier (BK, Type2690). Sixteen-bit quantization was performed, the sampling frequency was 200 kHz, and the measurement was recorded for 5 sec at each measurement point.

Consumer electronics

The second group measured VHF sounds radiated from consumer electronics and living wares in the laboratory of their university [12]. The most familiar products, a TV device, a refrigerator, an IH cooker, a ventilation fan, a hair dryer, a water outlet and a handheld shower head, were selected.The sound signals were recorded with sampling frequency of 19.2 kHz by a personal computer through the sound card connected to a condenser microphone of 1/4 inches in diameter (ACO Co., Ltd.; Type 4158N). The frequency spectrum was analyzed by a fast Fourier Transform (FFT) of2048 points with using Hanning window.

It was confirmed that the driving noises of IH cooker and hair dryer and water-flow noises for water outlet and handheld shower head have frequency components of VHF sounds above 16 kHz. As an example, the frequency spectrum of driving noise for two consumer electronics, IH cooker and hair dryer, are shown in Figure 4 (a) and (b). The driving noise of IH cooker has remarkable frequency components of VHF sounds. The peak frequencies of VHF sounds are

22.5 kHz, 45 kHz and 68 kHz, and their SPLs have over 65 dB. The driving noise of hair dryer also has frequency components of VHF sounds, although there is small contribution of VHF sounds to total energy of sounds as compared with IH cooker.



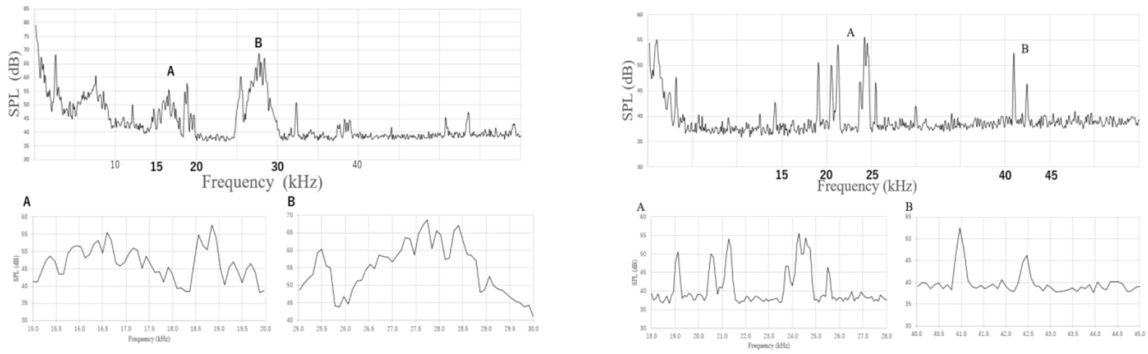
(a) VHF sounds radiated from IH cooker (b) VHF sounds radiated from hair dryer

Figure 4: Examples of VHF sounds radiated from consumer electronics.

Road traffic noise and conventional railway noise

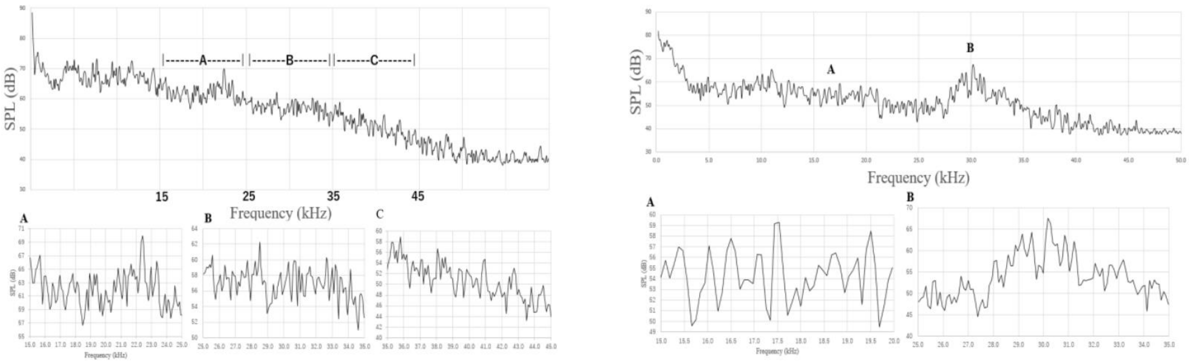
The third group measured VHF sounds included into road traffic noise and conventional railway noise [12]. They used a handheld measuring device (ROLAND Corporation; R-07) in this outdoor measurement. The road traffic noise was measured along with a video at two positions along urban road near to their university. The passing train noise was measured at the platform of station or the place along rail track. The interior train noise was also measured. The sounds were recorded in pulse-code modulation (PCM) with a sampling frequency of 96 kHz and a quantization bit rate of 24 bit. The frequency spectrum was analyzed by a similar way.

From measured results of the second group, it was confirmed that both road traffic noise and conventional railway noise have frequency components of VHF sounds above 16 kHz. The frequency spectra of vehicle interior and exterior noises are shown in Figure 5 (a) and (b). Both interior and exterior noise of vehicle has remarkable frequency components of VHF sounds. Especially, SPLs of VHF sounds of vehicle interior noise comes near to 70 dB. These measured results show that VHF sounds appear frequently while train is traveling. On the other hand, the comparison of sound with video of road traffic confirmed that VHF sounds were radiated from a truck, a bus and a light vehicle. As an example, the frequency spectra of noise radiated from passing truck and light vehicle are shown in Figure 6 (a) and (b). More or less, these vehicle noises have frequency components of VHF sounds. However, there are many events what the source of VHF sound could not be identified, because this urban road was always crowded. It needs to apply the method to detect sound source for measurement of VHF sounds radiated from moving automobiles.



(a) VHF sounds observed in a passing train (b) VHF sounds observed along railway line

Figure 5: Examples of VHF sounds radiated from a passing train [12].



(a) VHF sounds radiated from a truck (b) VHF sounds radiated from a light vehicle

Figure 6: Examples of VHF sounds radiated from a passing automobile [12].

EXAMPLES OF AUDITORY EVALUATIONS ON VHF SOUNDS

The fourth group measured VHF sounds include into train noises at interior train or at platform of station, and carried out auditory evaluation of those train noises including with VHF sounds at the same places. The fourth group consisted of four participants (university students) and a measuring staff [13]. The interior train noise was measured with a handheld measuring device (ROLAND Corporation; MGRE8). The sound signals were recorded in pulse-code modulation (PCM) with a sampling frequency of 96 kHz. The auditory experiment was carried out many times in the traveling trains which were shuttled between two stations. The participants continued to hear interior train noise while the train was traveling. They made a black round mark at its place on the map if they could recognize a VHF sound. Moreover, they made a X-mark at the same place on the map if would annoy the VHF sound. The occurrence of VHF sounds was verified by the sound spectrogram of the interior train noise.

The fifth group consisted of eight participants aged between 24 and 41 (average age 33 years old) who have healthy hearing ability (self-reported) and a measuring staff [14]. From answers of the questions on noise sensitivity (WNS-6B), four participants with WNS-6B score of 5 inclusive were determined as high sensitive to noise and the other participants were judged as low sensitive to noise. The participants stood side by side on edge of the station platform to be parallel to the railway track, and were requested to judge the sound of each passing train using the 26 adjectives. The passing train noise was measured using both a 1/2 inch's condenser microphone (RION Co., Ltd.; UC-53) and a digital recorder (RION Co., Ltd.; DA-20). The frequency characteristics of SPLs (Leq,40s) was analyzed to average sound energy of each 1/3 octave band at center frequencies from 100 Hz to 16 kHz during 40 sec including the passage of each train.Since the generation of VHF noise could be confirmed many times in the running train, the frequency analysis of the recorded data showed that VHF noise around 20 kHz to 35 kHz was indeed generated as shown in Figure 7-1. The results of the auditory evaluations for the third group, which continuously listened to the internal noise of the running train, revealed that all participants in the experiment could hear the VHF noise. Figure 7-2 shows the results of plotting the number of times the VHF sound was heard (stacked red and blue bar-graph) and the number of times the person felt uncomfortable (a blue bar-graph) in the express train on a map. The auditory evaluations on the discomfort of VHF sound showed that some of the participants felt uncomfortable, but others did not. The results of the auditory evaluations suggest that some young people with sufficient thresholds to hear the VHF sound may feel uncomfortable with the VHF sound heard inside the running train. Figure 8-1 shows the time-histories of the short-time frequency of wayside noise. This figure make it clear that the sounds of several sharp frequency peaks above 16 kHz are present immediately before and after the Shinkansen train passes. On the other hands, the high-frequency sounds become broad band noise above around 16 kHz when the Shinkansen train runs in front of the measuring point. From the results, it is found that the dominant frequency components of such high-frequency sounds are around 16 kHz. Figure 8-2 shows the relationship between the overall SPL including VHF sounds and average score of each 3 items for (a) timber and overall discomfort, (b) psychological effects and (c) physiological effects for the fourth group. Eight items excluded "(c) heavy in the head" are strongly correlated with the overall SPLs including high-frequency sounds. In other words, remarkably high intensity of high-frequency sounds causes an increase in the overall SPL of a train noise, and results in negative impact on the impression of the train noise. As for the sounds above 16 kHz radiated from rodent repelling devices in urban public space, it has been reported that the sounds causes negative impact on their impressions for people who can hear such sounds. Therefore, it is sufficiently guessed that the high-frequency sounds which greatly exceed to threshold of hearing perception might pose potential hazards for sound environment.

CONCLUSIONS

We have reported the recent activities and outlines for "ears project Japan". In the future, we will investigate the psychological and physiological influences of the sound generated on children and youths and then examine the feasibility of a more effective countermeasure and to create the knowledge for future guidelines and policy framework to enhance the wellbeing of citizens and protect them from health hazards associated with infrasound and ultrasound.

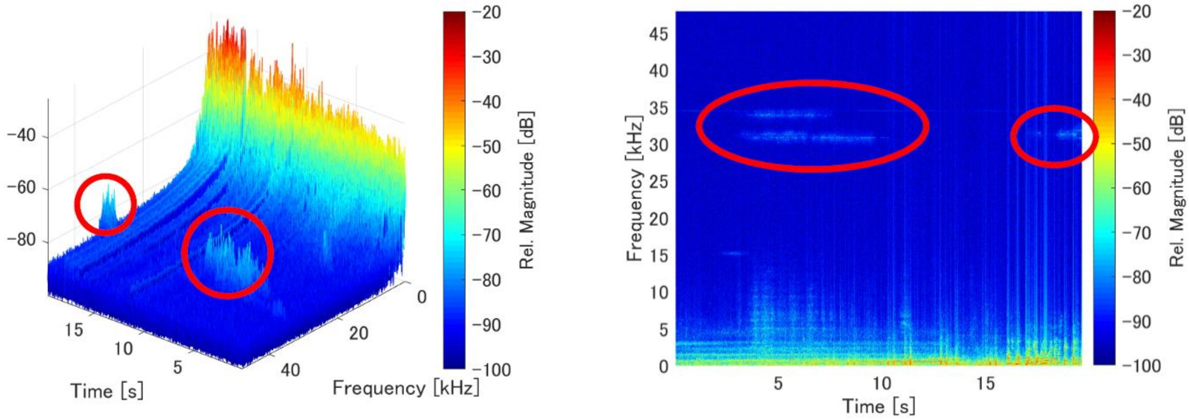


Figure7-1: Sound spectrogram of interior noise observed in a passing train.

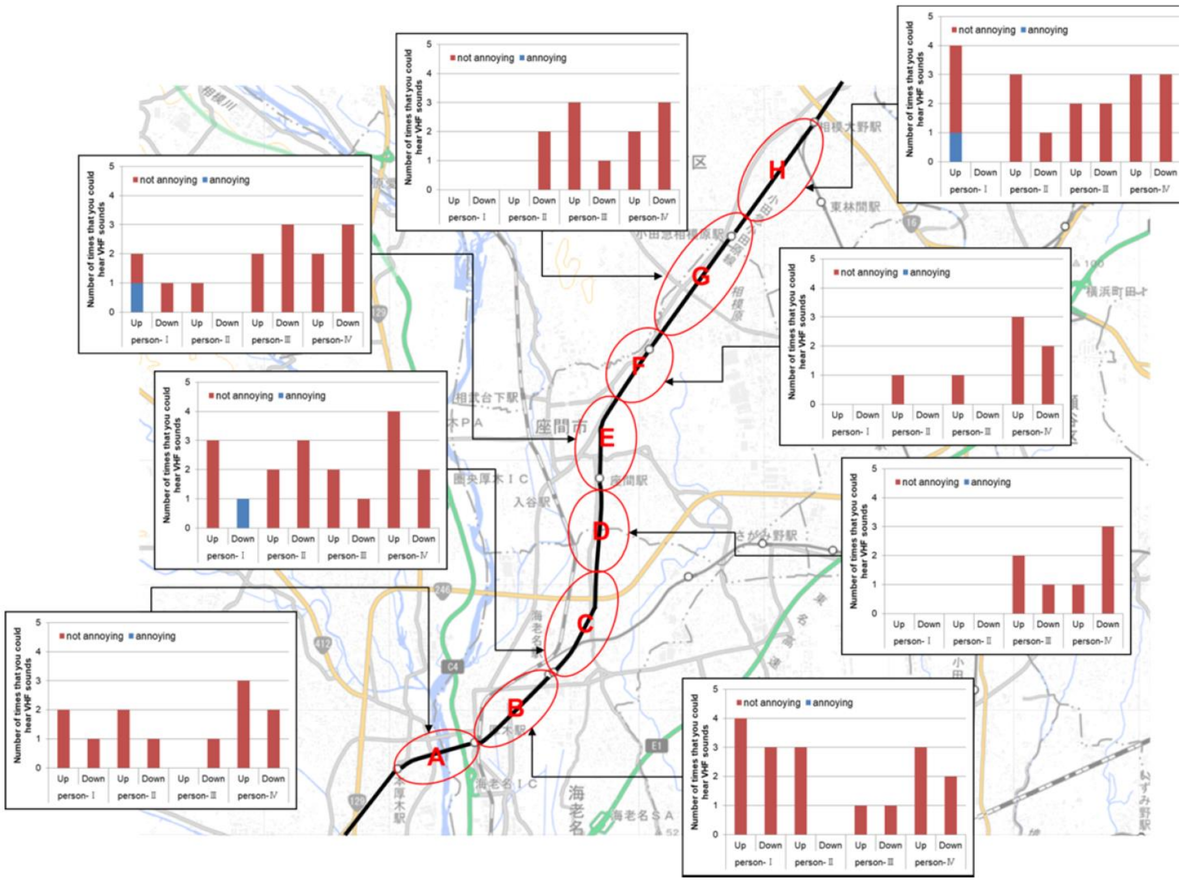


Figure7-2: Result of auditory evaluation test in a passing train.

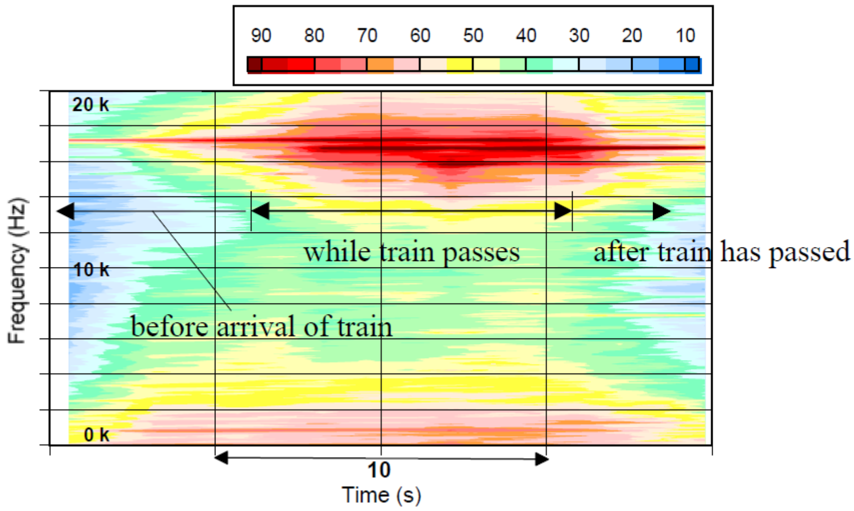


Figure8-1: Sound spectrogram of Shinkansen train noise observed at a station platform.

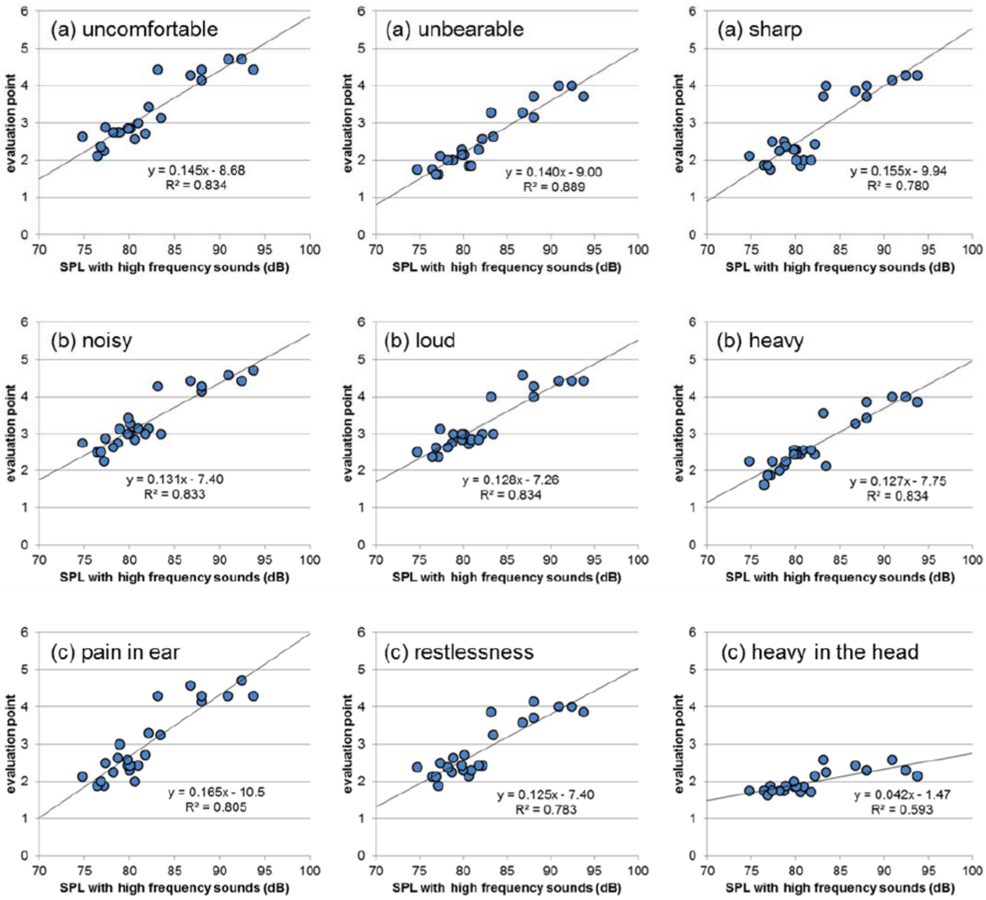


Figure8-2: The relationships between the overall SPLs with very-high-frequency sounds and average scores of each 3 items for (a) timber and overall discomfort, (b) psychological effects and (c) physiological effects.

Acknowledgements

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