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A Study on the Noise Reduction in Railway Vehicles using Bone Conduction Device : Railway noise analysis and Understanding Acoustic Characteristics of Bone Conduction Devices

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Abstract

Noise and vibration pollution is emerging to people in high speed trains. And it is difficult to realization of eco-friendly railway system at noise problem. The railway internal noise is 73dB on average and over 80dB in the loudest section. In order to reduce noise, there are passive methods that are far from noise sources and theother active noise reducion method. In this paper, we propose a method of reduce noise by measure and estimate the noise condition of train environment using Bone-Conduction device. We use an anti-phase waveform for canceling of noise characteristic. With this new system, the noise from surrounding environments can be reduced.

Keywords: *Railway Noise Environment, Noise Countermeasure of Railroad, Bone-Conduction Device, Active Noise Canceling.*

1. Introduction

The noise and the vibration pollution is on the rise by a social problem to the speedup of the railroad to the people who use the train inside or beside of the railroad. In addition, people who are linked with a railroad, and the diffusion rate of the railroad increases, and the noise standard to incarnate pro-environment railroad be strengthened, but the noise and vibration reduction measures are difficulty to actual effect. However not limited to the railway noise problem, people who are live in recent, use their portable multimedia devices in various places and they just want to use their devices more freely, whenever and wherever, regardless of the noise condition. However, if the users are being exposed to the loud sound through mobile devices for a long time, they may suffer noise induced hearing loss, and to other people can be another source of noise[1]-[5].

The noise is judged by subjectively that people do not like to hear the sound, however, using objective indicators with the standard, so the noise regulations and requirements of individual symbols is difficult to fully reflect, this reduction measures by each individual is also difficult to make[6].

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In this paper, we propose the method of according to changing conditions of the railway noise environment analysis to predict the effect of passengers in trains, and reduce the influence of noise. The proposed method, we use the microphone and bone-condition speaker for measuring the noise and generating the anti-phase sound.

This paper is structured as following. Chapter 2 investigates the usual the railway noise environment and noise reduce method. Chapter 3 discusses hearing and bone conduction hearing. Chapter 4 proposes the method for installing a bone-conduction speaker into the railway using. Chapter 5 examines the results of the experiment to evaluate the improved performance of proposed system after installing the proposed system. And conclude in Chapter 6.

2. Railway Noise Environment and Noise Reduce Method

We analyzed noise from various environments of status of railway condition and compared them to each other[1],[2]. In each condition, the noise was measured 10 times for 5 minutes each. Table 1 shows the average noise level for each environment. As shown in Table 1, the difference in average noise level between the quiet environment and noisy environment is about 7dB(A). However, there are the Worst case of the noise level is over the 85 dB(A). At The loudest moments, the train moves through the tunnel with the crossing event with speed over 250km/h. Although a few numbers of these moments are observed, typically using portable electronic devices due to the human in noisy environment, considering that condition is not negligible[6-8].

Table 1. Average Noise Level of each Environment

Condition		Sound Pressure Level
Loud Condition	High Speed	75dBA
	Tunnel	74dBA
	Crossing event	69dBA
	Etc.	69dBA
Calm Condition	Low Speed	63dBA
	Open Area	69dBA
	Etc.	65dBA

Figure 1 illustrates the frequency spectrum measured in a noisy environment in comparison to the one measured in a quiet environment. As noted in Table 1, there are the average difference between the noisy environment and the quiet environment, that is around 73dB(A). A lot of noise component is on low frequency bands and similar frequency peaks at 300-400Hz both of quiet and loud condition means room-resonance of inside of train.

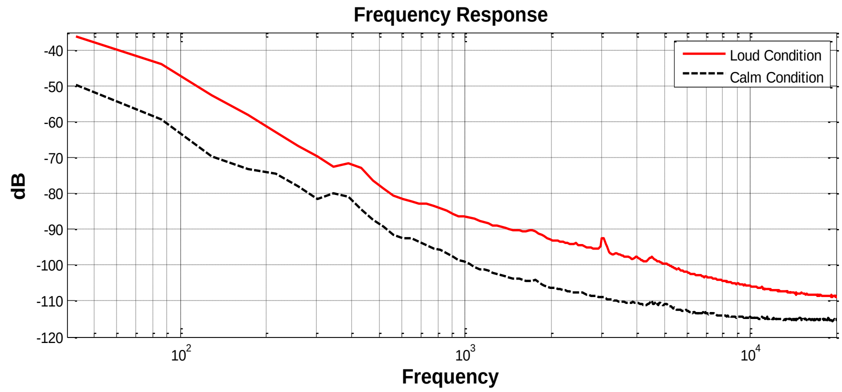

Figure 1. Frequency response of loud condition and calm condition

In generally, there are noise-reduction methods that have active and passive methods. In the passive method, it normally uses ear-plug or soundproof barrier for blocking the noise from people. And the method uses active technique, that uses the masking effect of human hearing or use the anti-phase sound of noise for control the noise [3][4][7].

In this paper, we use the active method that uses the anti-phase sound for reduce the noise interference. In this method, two sound sources which are the noise and the control sound, are opposite phase. However, that active technology is complex and difficult to realize when large space to control or many control component [9].

3. Human auditory characteristics

The ear is the organ of hearing and balance for mammals. It is usually described as having three parts, the outer ear, middle ear and the inner ear. The figure 1 shows the structure of human ear. The outer ear consists of the pinna and the ear canal. Since the outer ear is the only visible portion of the ear in most animals, the word ‘ear’ often refers to the external part alone. The middle ear includes the tympanic cavity and the three ossicles. The inner ear sits in the bony labyrinth, and contains structures which are keys to several senses: the semicircular canals, which enable balance and eye tracking when moving, which enable balance when stationary. And the cochlea, which enables hearing. The ears of vertebrates are placed somewhat symmetrically on either side of the head, an arrangement that aids sound localization. The ear corresponds to a transducer that converts a small energy sound wave into an electrical signal of the auditory nerve.[8-10]

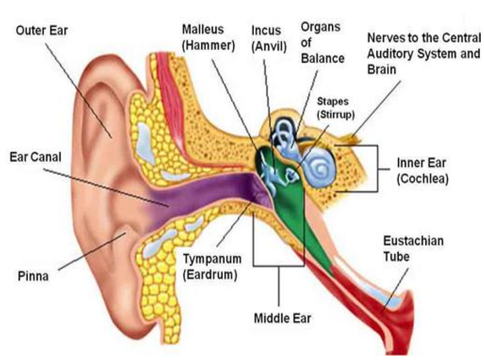

Figure 2. Structure of Ear[8]

Sound waves travel through the outer ear, are modulated by the middle ear, and are transmitted to the vestibulocochlear nerve in the inner ear. This nerve transmits information to the temporal lobe of the brain, where it is registered as sound. The inner ear houses the apparatus necessary to change the sound and vibrations transmitted from the outside world via the middle ear into signals passed along the vestibulocochlear nerve to the brain. The hollow channels of the inner ear are filled with liquid, and contain a sensory epithelium that is studded with hair cells. The microscopic ‘hairs’ of these cells are structural protein filaments that project out into the fluid. The hair cells are mechanoreceptors that release a chemical neurotransmitter when stimulated. Sound waves moving through fluid flows against the receptor cells of the organ of Corti. The fluid pushes the filaments of individual cells; movement of the filaments causes receptor cells to become open to receive the potassium rich endolymph. This causes the cell to depolarize, and creates an action potential that is transmitted along the spiral ganglion, which sends information through the auditory portion of the vestibulocochlear nerve to the temporal lobe of the brain [8].

Figure 2 shows the positions resonating to acoustic frequencies when these cochleas were deployed. And information up to 3,000 Hz, which contains the most important information in human voice, accounts for more than half of the acoustic frequency detection area of cochlea. The human ear can generally hear sounds with frequencies between 20 Hz and 20 kHz (the hearing range), and the cells are distributed evenly in the cochlea, but the main resonance sounds are different [9].

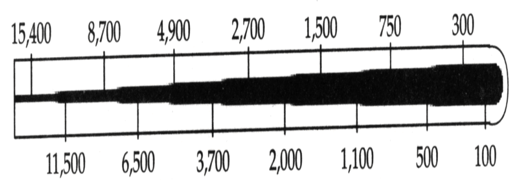

Figure 3. Acoustic frequency location of Cochlea[8]

Bone conduction is the conduction of sound to the inner ear through the bones of the skull. Bone conduction transmission can be used with individuals with normal or impaired hearing. In addition, bone conduction and general hearing can be seen as a way of hearing the same sounds. Bone conduction is one reason why a person's voice sounds different to them when it is recorded and played back. Because the skull conducts lower frequencies better than air, people perceive their own voices to be lower and fuller than others do, and a recording of one's own voice frequently sounds higher than one expects it to sound. However, bone conduction and air conduction have different transfer functions in delivering sound, and the bone conduction hearing equivalent threshold model is used to match them [10].

4. Active Noise Reduction System with Bone-Conduction Speaker

The Active noise control, the algorithm is simple to implement, but the limitations of the actual realization, so passive noise reduction method is primarily developed and has been spread. The propose method in this paper, use bone conduction speaker for the active noise control at the headrest of the seat in the personal space of the train. Figure 4 is the block diagram which outlines the method proposed in this paper. An additional microphone receives the noise and then the noise passes through the bone conduction noise cancellation system. The bone-conduction speaker generates the vibration of anti-phase noise and eventually decreases the noise level. In this system, we cancel the noise at cochlea by applying a destructive-interference with the anti-phase of environment noise. As the environment noise undergoes the continuous analysis and reduction process this way, the system actively reduces the noise.

In our previously study, we have been researched the characteristics of bone-conduction speaker systems [1][2] and the sound propagation method. And this technique is applied to reduce the noise interference, that people can use a quiet railway system.

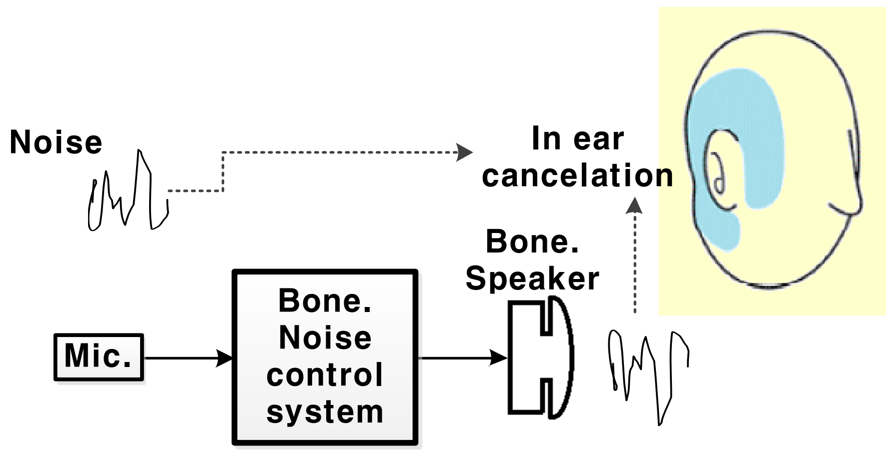

Figure 4. Block diagram of proposed method

5. Experiment and Result

In order to evaluate the performance of the proposed system in this paper, we conducted an experiment in the anechoic chamber where the background noise was 30dB. We set the 80 dB noise environment condition using monitor speakers. To evaluate the performance of the bone-conduction system, a vibration sensor and an additional microphone were attached to the homemade headrest. We measure the time response which is compare with the microphone input and bone-conduction output. And then, we extract the modeling parameter of entire system for compensation.

Figure 5 shows the experiment result of input and output signal. The upper line is output signal form bone-conduction speaker, lower line is input sound signal from microphone and middle line is the result of summation of upper and lower.

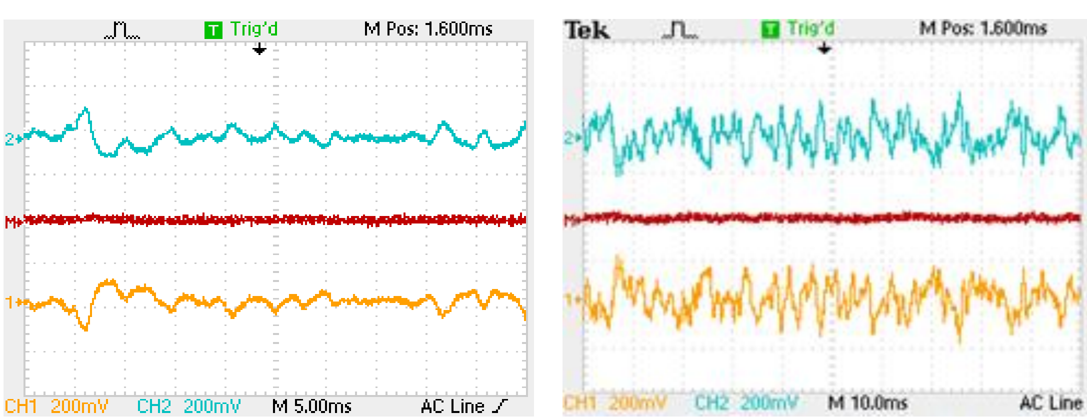

Figure 5. Waveform of input and output signal

6. Conclusions

The railway noise is raised by a social problem to people who use and around train and railroad, caused by high speed train. And people want to use that the train are more quiet, safe and comfortable. In this paper, we suggest the active noise control method for quiet environment using bone-conduction speaker. And the advantages are less effort to get the effect to control the noise then in a large space noise control, and this system reserves normal hearing with air-conduction for announcement, portable device and mobile phones. On the other side, the system performance is influenced by contact point and the bone-conduction speaker from the people, either that is difficult to interpret the performance. So we are studying control technology for remedy system′s shortcomings.

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