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Improvement of Sound Quality of Voice Transmission by Finger

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Abstract

In modern society, people live in an environment with artificial or natural noise. Especially, the sound that corresponds to the artificial noise makes the noise itself and affects each other because many people live and work in the city. Sounds are generated by the activities and causes of various people, such as construction sites, aircraft, production machinery, or road traffic. These sounds are essential elements in human life and are recognized and judged by human auditory organs. Noise is a sound that you do not want to hear by subjective evaluation, and it is a loud sound that gives hearing damage or a sound that causes physical and mental harm. In this study, we introduce the method of stimulating the human hearing by finger vibration and explain the advantages of the proposed method in various kinds of a noise environment. And how to improve the sound quality to improve efficiency. In this paper, we propose a method to prevent the loss of hearing loss and the transmission of sound information based on proper signal to noise ratio when using portable IT equipment in various noise environments.

Keywords: *Finger acoustic transfer, Environment noise condition, Prevention noise induced hearing defect, Enhancement of Signal to Noise Ratio.*

1. Introduction

In modern society, people live in an environment with artificial or natural noise. Especially, the sound that corresponds to the artificial noise makes the noise itself and affects each other because many people live and work in the city. Sounds are generated by the activities and causes of various people, such as construction sites, aircraft, production machinery, or road traffic [1]. These sounds are part of modern human life. And it becomes an important and essential life element [1][2]. With the development of information communication and communication technologies, people receive various kinds of sound information through small portable devices [3][4]. Whether the situation where the person is located is loud or quiet, he constantly uses his mobile device. At this time, there is a method of receiving information directly by generating sound directly from the device or by transmitting sound directly to the ear, such as an earphone [4][5][6]. If the device emits sound directly, it will transmit unwanted information or sound to nearby people, which will direct the sound directly to the ear, such as earphones and headphones [6][7]. Previous studies have shown that when transmitting information using portable devices, the noise environment can impair user hearing [7][8]. Typical portable IT devices can be used in quiet environments as well as in quiet environments without special tuning [8]. In addition, the sound generated by the portable information communication device may be the noise of other people around and interferes with the communication or information collection among the people [8]. However, people are constantly using portable IT devices. And IT equipment manufacturers do not interfere with the

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transmission of information in noisy environments by producing large sound pressure levels that are sufficient to meet the needs of these users [8][9].

However, indiscriminate use of portable IT devices can result in severe noise-induced hearing loss [2][4][8]. In previous studies, the average SNR should be greater than or equal to 15 dB, taking into account human hearing characteristics. And the size of the environmental noise can affect the hearing loss considering the part that affects information transmission. Generally, because of the auditory characteristics, the size of the sound signal used for communication is sufficient to conceal ambient noise, so no noise is lost when transmitting information [8]. Otherwise, in the human ear, the necessary information is masked by noise, which degrades the quality of information transmission. The average SNR required is 15 dB [9]. In order to maintain a high SNR of more than 15dB, there is a method of distancing the signal source and the noise source or making a sound interference. In rare cases, there is a method of analyzing a noise source and combining the opposite phase signals to reduce the influence of noise by an active noise reduction system. Basically, when people acquire acoustic information in a noisy environment, blocking the other ear that is transmitted only by noise and making a phone call can be seen as a method of self-reliance from noise [10].

Previous studies have classified the noise environment using mobile IT devices by size and type [11]. Particularly, noise and quiet environment are divided into size and frequency characteristics. The noise level of the noise in the noisy environment is 80dB, and it is getting closer to the machine making the noise in the daytime [2][11]. As for the frequency characteristics, it shows high energy in the band of 200-3000Hz, and it uses human voice information to transmit information. There are two ways to overcome this noisy environment and utilize IT equipment smoothly [12]. There are the passive noise isolation and the active methods [13]. Passive methods include a method of getting away from a source of a noise and a method of shutting off through a plate or membrane in the path that noise effects. Active methods include using noise canceling phenomena through the noise and precisely the opposite phase. In the case of ANR using extinction interference, it is theoretically simple, but it is difficult to make it to various limitations to realize in reality. The sound produced by one ANR system can act as a different noise in a large space due to the phase difference [12][13].

Considering various noise environment in portable audio equipment, the sound is made larger than noise for smooth information transmission and supplied to users. And the sound that is made is transmitted to the person and is recognized by stimulating the auditory organ cell. At this time, the stimulation of strong energy damages the cheek cells, which causes permanent hearing loss. Various methods have been introduced and studied in previous studies to protect hearing from noise and loud sounds. In this study, we introduce a method of using vibrations speaker as a method to cut off noise and transmit only sound signals directly. And we study how to improve the quality of sound transmission by this method. In the process of recognizing the acoustic signal that occurs in the auditory organ in the brain, there is a method of transmitting by air and a method of directly transmitting vibration. Among them, a method of transmitting a direct vibration transmits a signal and recognizes it.

2. Human Ear and Hearing-Loss

2.1 Human Ear

Ears are the institutions responsible for the hearing of people and can be divided into the inner ear, middle ear and outer ear. The ear corresponds to a transducer that converts the sound signal (pressure change of the air) through an auditory nerve into an electrical signal. In addition, the human ear evaluates acoustic signals existing on the outside of a person, and judges the types and characteristics of sounds occurring in a person's surroundings and determines them. In addition, these characteristics can be heard and judged based on objective and subjective criteria, and various information such as language and language are given by evaluating the amount and type of sensation. It is composed of the auricle, ear canal, and eardrum, and collects the external sound and transmits it to the middle ear. It plays the role of amplifying the acoustic signal in the three-dimensional space by clarifying the difference between the component of the sound and the characteristic delay of the signal depending on the shape of the auricle. The middle ear contains ossicles and eustachian tubes and consists of three small bones. The middle ear adjusts the acoustic impedance of the air and inner ear's sound transmission characteristics so that the vibration of the air is transmitted to the inner ear. The inner part is the innermost part of the cochlea with the cortical organs and is fluid and spiral. In the actual inner ear, the shaking of the air molecule is converted into an electrical signal, and the detailed structure, illustration, and explanation are given in [2][8][10].

The process by which humans perceive sound [10] is that the sound source is transmitted through the air in the form of a pressure wave and then through the ear canal to the brain through the nervous system. The transmitted acoustic signal is perceived in the human brain and basically determines the perceived sound information. For example, in the case of speech, it is the basic function of interpreting language information and conveying meaning or knowledge. They also recognize the language, emotion, health, and identification of individuals. It also assesses the quality of the ear when listening to music or sound and assesses whether the quality of the sound is good or bad. The objective and subjective evaluation of the sound heard in our ears also creates indicators by the cerebral origin and empirical knowledge [8-12].

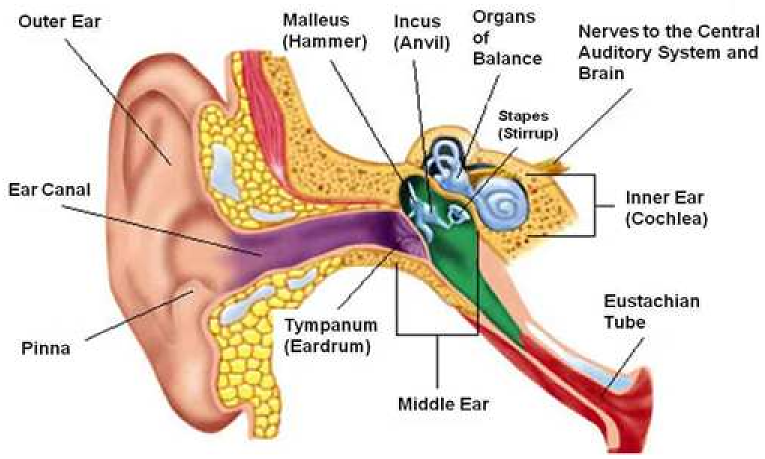

Figure 1. Structure of Ear[12]

There are several characteristics of human hearing that recognize the sound. First, the condition that recognizes the size. Second, conditions that recognize the frequency [12]. Third, it is divided into the conditions for the duration of the sound. The size represents the change in the pressure or pressure that the air molecule pushes and pulls the eardrum easily enough to show the intensity of the sound, and expresses using the unit of decibel using the algebraic change unit based on the smallest sound 0dB the human can hear. When the magnitude of the sound that a human being can hear is represented by the pressure change, it expands more than 1 billion times, and exponential processing of the increase and decrease becomes. Frequency refers to the height of the sound, and counts how many times per second the vibrations of the air molecules have oscillated. It is an independent parameter for each frequency, which is the height of the sound, and is difficult to produce through a combination of air and can be controlled only by the exact matching frequency. In humans, the frequency is perceived by the resonance frequency stimulation of the auditory cells of the inner ear. Duration is a measure of the length of a sound that exists and does not exist. A person can finally judge the difference of three independent parameters by size, height, and time, and utilize it to obtain information from the sound. In recognizing the size and frequency of auditory characteristics, physical changes are not recognized linearly, and measures such as equal loudness contour are used to correct for these changes. It is intended to convert objectively the evaluation of subjective size, and it can be seen as a condition that recognizes the size of the sound transmitted through the air. This is shown in Figure 2 below [13].

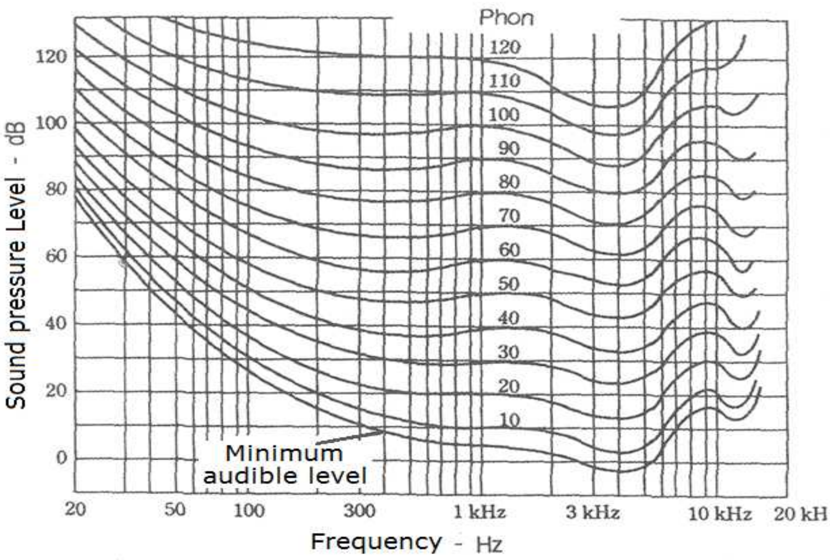

Figure 2. Equal-loudness contour [13]

2.2 Bone Conduction Hearing

There are two major ways of sound transmission by people who recognize the sound. One is the air conduction method by air that hears the general external sound, and the method of recognizing the sound as described above is the external ear, middle ear, and inner ear [9]. And another method of shearing the sound is the method of recognizing the sound by bone conduction. In other words, bone conduction is a method of perceiving the sound of the inner ear caused by the sound of the bone around the inner ear, and collecting the vibration of the air, which corresponds to the role of the outer ear and middle ear, and the acoustic impedance between the air and inner ear's cortical organs [10] Although auditory hallucinations are not well known, vibrating loudspeakers directly contact the bones around the ears to transmit sound, so that the sound transmitted through the ear canal Even if the sound transmission by hearing is prevented, the sound is delivered directly to people who use earplugs. This bone conduction is used to prevent water from reaching the ear as in the swimming pool, to use the earplug for protecting the hearing when communicating or working in noisy environments, and to transmit information at the same time. In this study, SNR was improved and sound information was transmitted by blocking noise transmitted to the air and transmitting sound by bone conduction [10][13].

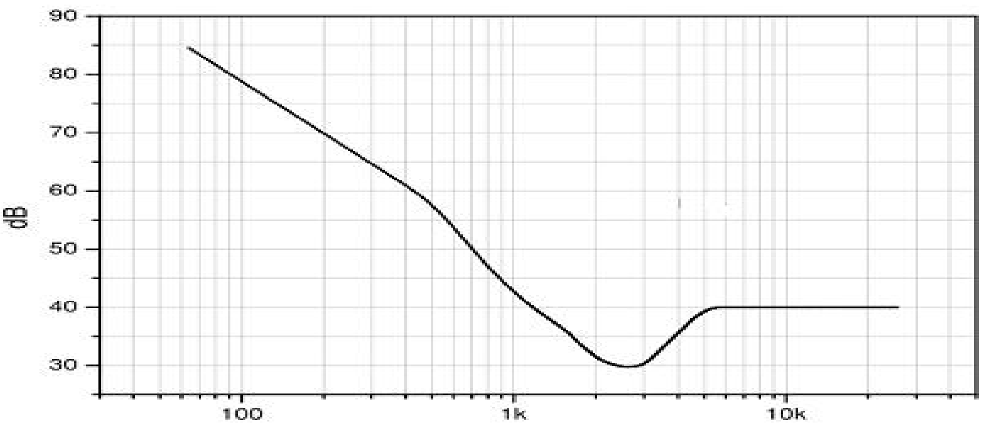

Figure 3. bone-conduction loudness contour [10]

2.3 Hearing loss

Hearing impairment does not appear as easily as other disorders. Even if hearing damage is severe, it can be difficult to check. Healthy people have an audible frequency range of 20 to 20,000 Hz, but there is a limited range of frequencies and sizes of sounds that can be heard as a result of aging. As the aging progresses, the audible frequency band decreases and gradually decreases at the high frequency endpoint of the audible band [4][10][14]. In addition to aging, hearing is damaged by noise, and the aging of cells is accelerated by the influence of loud sounds. In this paper, the auditory loss can be caused by loud sounds generated in portable devices. This is classified as sensory neural deafness, and sensory nerve deafness is the result of the inner ear or cochlear damage, and even if the cause is removed by factors such as aging, continuous noise or medication, and cochlear and inner ear damage is not easily recovered [15][16]. A person is exposed to a large sound pressure for a long time and causes a deterioration of hair cell function inside the cochlea. Since auditory hair cells can be regenerated, temporary damage can be recovered, in part, within 24 hours, and generally within 72 hours. However, permanent hearing loss can occur if the ability to regenerate hair cells is significantly reduced, such as when frequent repetitive hearing loss occurs [17].

3. Propose method and experiment

3.1 Bone Conduction Hearing with Finger Vibration

In the previous study, the basic method and the method of the sound transmission using the finger were explained, and the method proposed in this study means to measure and compensate the sound transmission characteristic of the finger. The acoustic impedance coefficient of the finger is different from that of the air conduction. [11] The equivalent loudness curve of the general hearing can be calculated through the equivalent circuit of the bone diagram through the transfer circuit of the equivalent bone conduction power level as shown in Fig. 2. The low frequency vibration is attenuated and the mid frequency Low attenuation and high frequency have the characteristic of passing properly. And since it passes through the fingers, it is necessary to analyze the sound transmission loss and characteristics of the finger together. For compensation, sound quality is improved if compensation is made by air conduction-bone conduction equivalent circuit model of human hearing basically. This bone conduction equilibrium level is used to make primary compensation and to apply the weight of 80phon which is to be transmitted by the loudness curve of the human auditory characteristic. In addition, the sound quality is improved by compensating again through the acoustic transmission coefficient of the finger.

Figure 4 shows the structure of a typical vibration speaker. The frame is the skeleton that forms the structure of the bone conduction speaker. Yoke acts as a metal to form a magnetic circuit. The permanent magnet is a permanent magnet through the magnetization, and the top plate serves to concentrate the magnetic field of the magnet and focus it on the voice coil [10]. The Vibration Plate serves to transmit the up and down movement transmitted through the voice coil to the bones of the human body [10]. Suspension plays a role to prevent structural damage by vibrating the vibrating body when the large signal comes in, causing the bone conduction speaker to vibrate with enough amplitude to withstand. The cover ring serves to fix the suspension to the frame. Then, the vibration begins at the wrist, and the vibration is directly transmitted to the vicinity of the skull through the finger to perceive the sound.

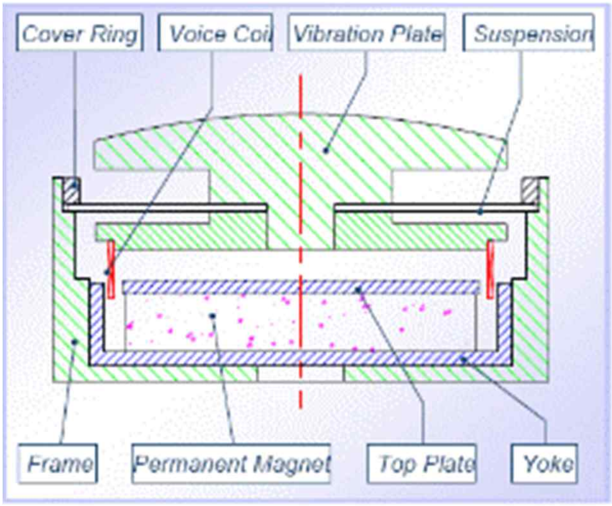

Figure. 4. Structure of Bone Conduction Speaker [8]

3.2 Propose Sound Enhancing Method

Introduced in the previous chapters, and utilizes sound transmission by direct transmission of vibration, which describes its principle. For this study, the oscillating bone conduction speaker of Fig. 4 is used. The vibration and sound generated in this way transmit vibration in the form of close contact with the wrist, and the vibration is transmitted through the wrist, hand, finger joint, and finger bone. Existing bone conduction speakers can predict responses using bone conduction equivalent threshold levels. However, if the proposed method is used, not only the corresponding equivalent circuit but also compensation by the acoustic transmission coefficient of the finger is required to accurately transmit the desired sound. This is because the sound transmission characteristics of the hand and the finger are different in addition to the acoustic characteristics of the bone conduction speaker. And since it passes through the fingers, it is necessary to analyze the sound transmission loss and characteristics of the finger together. If we look at this, if we add loss of bone conduction equivalent circuit and finger sound transmission, we have the structure to transmit only specific frequency. In addition, it is necessary to predict the shape and attachment force of the wrist and the bone conduction speaker in contact with each other and to compensate for the deficiency in advance. By compensating for these characteristics to reproduce and reproduce vibration-sound, it is possible to efficiently transmit sound even though the bandwidth is limited.

3.3 Experiment and Result

The result of measuring these characteristics is the frequency response diagram shown in Fig. Figure 5 shows the response curves of the solid black line after the improvement. Compared to the curve of the blue-dotted line, the 1000Hz and 1100Hz bands are compensated, and the output is improved over the entire frequency band. In addition, it can be confirmed that the response in the 3400 Hz band, which is sensitive to the human ear, is smooth and well controlled. And, the response of the used frequency band over 5000Hz is improved, and the response of the frequency band that can raise the intelligibility and the response of the human ear-sensitive band are improved. In addition, it was confirmed that the frequency band at which the attenuation by the wrist and the finger occurs corresponds to the middle and low frequency of less than 1 kHz, Different results were obtained each time, confirming the need for further study.

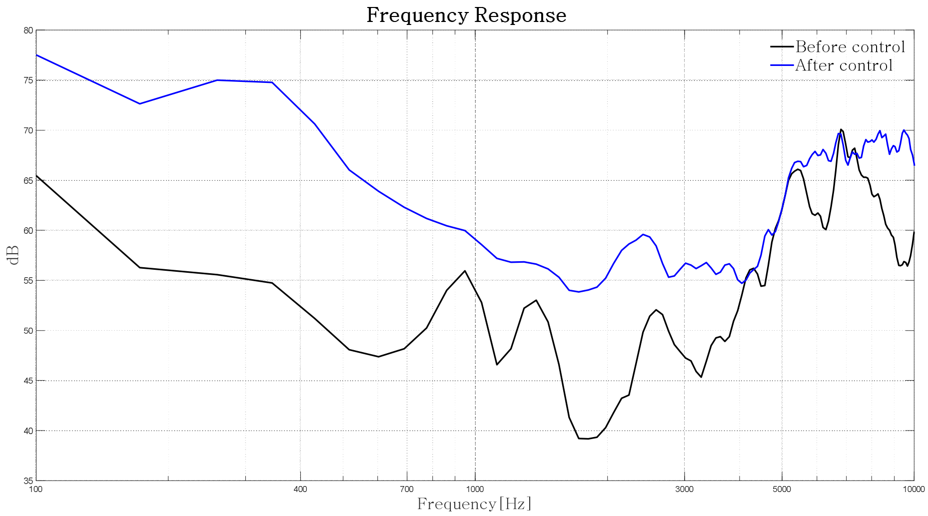

Figure. 5. Frequency response of control

Figure 6 shows the result of predicting the final frequency response that a person hears, and the degree of the stimulation of the human auditory sense by the sound of the bone conduction speaker shown in Figure 3. The low-frequency part of Fig. 3 shows the characteristic that attenuation occurs a lot and the peak part of 2,300Hz band in Fig. 5 is also emphasized. In addition, it is predictable that the low frequency part below 1000Hz must be compensated to be similar to the sound of a typical speaker. However, since low-frequency vibration should include strong energy, it is desirable to add the necessary compensation as much as the response expected in consideration of the wrist, fingers and joint health.

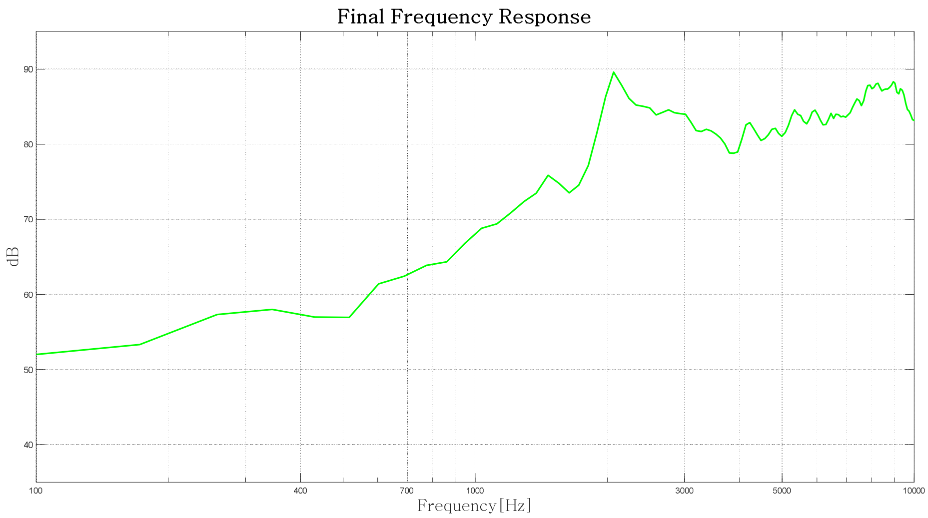

Figure. 6. Estimated frequency response of hearing with finger vibration device

4. Conclusion

In this paper, we show how to utilize mobile IT equipment in a noisy environment by using proper SPL and SNR to use portable IT devices. People want to use audio equipment appropriately regardless of the degree of environmental noise. However, using a portable acoustic device in a very noisy environment can cause noise-induced hearing loss. Therefore, we applied the appropriate SPL and SNR in the previous study and introduced the sound transmission and sound blocking method using the vibration in consideration of the kind of exposed noise. In the proposed method, the vibration generated in the wrist part rides on the finger and hears the sound by using the bone hearing. In this method, the noise transmission through the ear canal is blocked by the finger, and the SNR can be increased by more than 10 dB. Further, even if the vibration generated by the bone conduction device is directly transmitted to the auditory organ and the ambient noise is noisy, there is an advantage that the high SNR can be maintained. Considering these characteristics, the SNR is improved by more than 20dB. However, there is a disadvantage in that the acoustic characteristics can be changed depending on the vibration transmission characteristic of the finger and the contact type and position. In the future, further research will be conducted on the control method and the sound reproduction method for correcting these characteristics.

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