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An Acoustic Analysis of Noise Environments during Mobile Device Usage

Hyung Woo Park

Dept of Information and Telecommunication Engineering, Soongsil University, Seoul, Korea
pphw@ssu.ac.kr

Abstract

In contemporary modern society, people are constantly exposed to many kinds of noise, such as that from machinery, aircraft, construction sites, or road traffic. Noise is considered one of the most indispensable and influential parts of human life. This study investigates the acoustic characteristics of noise transfer from external sources to the human ear. For this study, we measured and analyzed various types of noise environments, installed monitoring speakers in a semi-anechoic room, and conducted intentional noise-filled experiments. In this environment, the size of the sounds generated by use of a portable device was also measured and the SNR (signal to noise ratio) calculated to study the influence of the noise. As sound is transmitted to the ear and the human body, it affects not only auditory damage but also other parts of the body. In this paper, we propose a proper SNR for noise emitted by portable IT equipment to prevent hearing loss when IT equipment is used.

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

1. Introduction

In contemporary modern society, people are exposed to many kinds of noise, such as that from machinery, aircraft, construction sites, or road traffic. Noise is simply part of the fabric of modern human life. With the development of information and communication technologies, people can communicate in noisy environments using portable IT devices. Furthermore, the spread of such portable IT devices, including mobile phones, has been pervasive, and many people now own more than one such device. Additionally, the volume and frequency of information transmitted using mobile devices has increased. Further, it is generally well known through previous research that user noise when transmitting information using such a portable device may cause damage. Portable IT devices can be used in quiet environments as well as in noisy environments without any special adjustments [1]. In addition, any sound generated by a portable information communication device can be interpreted as noise to another person in the vicinity, and may become an element that interferes with a call or information acquisition [2]. However people are constantly

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Corresponding Author: pphw@ssu.ac.kr
Tel: +82-2-820-0936
Dept of Information and Telecommunication Engineering, Soongsil University, Korea

using these devices. And IT equipment makers generate large sound pressure in accordance with the demands of these users, so that they do not interfere with information transmission in noisy environments [3].

However, the indiscriminate use of mobile devices can cause serious hearing loss, given that the average signal-to-noise ratio (SNR) for a call must be 15 dB or more, in consideration of human hearing characteristics [3-6]. This is because, due to the auditory characteristics of a general person, the size of the sound used for communication must be large enough to mask ambient noise, so that no loss occurs when information is transmitted [7]. Otherwise, when trying to reduce the amount of noise introduced into the gap between the ear or the ear and the handheld device, the 15dB SNR is maintained and conversation is possible [8].This is also the reason why people using cell phones occasionally block their opposite ears when making calls in noisy environments [9].

In order to overcome the obstacles inherent in such noisy environments portable It devices transmit processed noise between mobile devices. Estimating any ambient noise during the call, removing this noise from the voice input via a microphone, and then sending only the voice, the receiving side can fairly accurately reproduce a sound that is less influenced by background noise [6]. However, it is not easy to find a phone that uses noise reduction technology based on environment analysis and implementation algorithms. The volume of the sound signal used in a noisy environment is equivalent to an average sound of 100 dB [7]. This amount of sound is loud enough to quickly and temporally damage a person's hearing [8]. If such a loud noise is produced near the ear, the auditory cells will be damaged in a very short time [5]. In this paper, we investigate sound propagation using the finger that transmits the signal and reduces the influence of the noise in the information transmission using the portable device.

In Chapter 2, we examine human hearing and hearing impairments in general. Chapter 3 explains the usage environments of portable IT equipment. Chapter 4 sets out the experiment and its results, and Chapter 5 contains conclusions.

2. Human Ear and Hearing-Loss

2.1 Ear structure and characteristics

The Ear is the organ responsible for hearing, and it can be anatomically divided into the inner ear, middle ear, and outer ear. The ear corresponds to a transducer that converts a very small amount of energy sound into an electrical signal through the auditory nerve [10]. In addition, the human ear evaluates external acoustic signals, and is the basic sensory organ that grasps and judges the type and characteristics of the sound generated in a person’s surroundings, and transmits this information to the brain [9]. Further, these factors provide a basis for evaluating sound by subjective standards as well as grasping information through the objective sound of this sense. . The external ear consists of the pinna, the ear canal, and the eardrum. The middle ear includes the ossicles and the eustachian tubes, and the three small bones known as the hammer, anvil and stirrup bones. This is the innermost part of the cochlea where there is also found the organ of corti, and it is fluid and spiraling. Detailed structures, illustrations and explanations have been provided in [8][10]. The process by which humans recognize sound starts when [10], the sound source is transmitted through the air as a wave and is then transmitted from the ear canal to the brain through the nervous system. The transmitted acoustic signal is recognized in the human brain and basically determines the information of the perceived sound. For example, in the case of voices, it is a basic function to interpret linguistic information and communicate meaning or knowledge. Further, when you listen to music or sound, the ear evaluates the quality and whether a sound is perceived as good or bad. In addition, objective and subjective evaluations of the sounds heard in our ears produce good indicators of sound [8-12].

The auditory structure of the human ear is divided into three parts that consist of the outer ear, middle ear and, inner ear. The process of hearing basically involves transmission of air vibrations. Audition is the scientific name for the sense of sound. Sound is a form of energy that moves through air, water, and other matter, in waves of pressure. Sound is the means of auditory communication, and includes such varied forms as frog calls, bird songs and spoken language. Although the ear is the vertebrate sense organ that recognizes sound, it is the brain and central nervous system that "hears". Sound waves are perceived by the brain through the firing of nerve cells in the auditory portion of the central nervous system. The ear changes sound pressure waves from the outside world into a signal of nerve impulses sent to the brain [13-14].

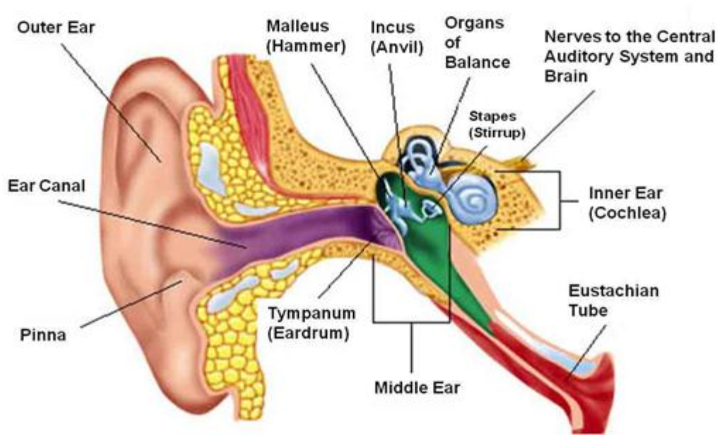

Figure 1. Structure of Ear[14]

Our hearing has several characteristics. First, there is a logarithmic scale that increases in frequency and magnitude. Even when a person hearing a sound recognizes the frequency, the low frequency is sensitive and the high frequency is insensitive. In recognition of the size, there is a characteristic of recognizing that it increases linearly when it increases logarithmically. This is known as the equal-loudness contour as shown in Figure1 2 [10]. In the time and frequency domains, there is a masking effect that causes loud noises to drown out neighboring sounds. As a result, when people talk in a noisy environment or hear a sound, this device will be activated and this will damage human hearing. It is generally accepted that hearing damage begins to occur from 80 dB in human hearing [11].

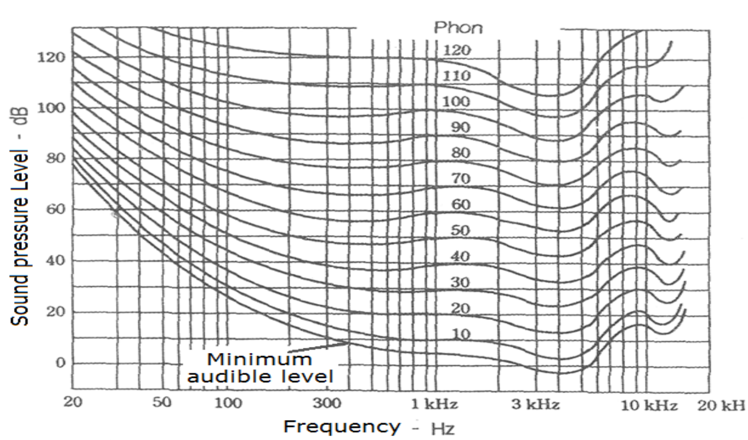

Figure 2. Equal-loudness contour[11]

2.2 Hearing loss

Hearing loss is not easily recognized compared to other disorders. Even if hearing damage is severe, it can be overshadowed. Healthy people have an audible frequency range of 20 ~ 20,000 Hz, but limits on the range of sounds that can be heard increase with aging. In addition, as the aging process progresses, the audible spectrum decreases and the audible range gradually decreases from the high frequency end [10].

Hearing loss is classified into various types according to cause and phenomenon. In this paper, we investigate hearing loss caused by car audio equipment. If hearing loss is caused by a loud noise, it corresponds to noise-induced hearing loss, one type of sensory nerve impairment. Sensory neural deafness is the result of damage to the inner ear or the cochlea, and is caused by such factors as aging, continuous noise, or drugs, and even if the cause is removed, damage to the cochlea and inner ear is not easily restored [11].

Noise-induced hearing loss occurs when a person is exposed to large sound pressure for a long time, and the hair cells inside the cochlea are damaged, resulting in hearing ability being lowered. Noise-induced damage of hair cells affects the outermost hair cells near the fenestra ovalis of the cochlea, and sound gradually becomes inaudible from the high frequency to the speech band (250 ~ 8,000 Hz) [11].

Auditory hair cells are capable of regenerating, so that temporary damage can be recovered, in part, within 24 hours and overall within 72 hours. However, permanent hearing loss may occur when the ability to regenerate hair cells significantly decreases, as when transient hearing loss is repeated frequently. Table 1 shows the allowable listening times per day according to the sound pressure levels specified by the Occupational Safety and Health Administration (OSHA). Exceeding the times allowed for sound pressure levels can damage hair cells and cause loss of hearing [11].

Table 1. Allowed Hearing Time by Sound Pressure Level [11]

Sound Pressure level	85dB	90 dB	95 dB	100 dB	105 dB	110 dB
Aloud time	16H	8H	4H	2H	1H	0.5H

3. The noise Environment of Portable Devices Usage

3.1 Measurement of environment noise

It is necessary to measure various noise environments as comparison targets, which we have done classifying noise into representative environments using several portable IT devices. The repeated recording and the average sound pressure were measured by dividing the situations into place and time. Measurements are made using the Bruel & Kjaer precision sound pressure analyzer type2260 and a notebook PC with a microphone recording at 44.1kHz sampling rate and 16bit mono quantization bits. Table 2 shows the measured values. For Table 2, the average noise sound pressure level in a noisy environment is around 80 dB, and the average noise level of a calm environment is around 58dB. However, in some of the noisiest situations, the value of noise level is more than 100dB. In such an environment there is a high likelihood that people will turn up their mobile device sound.

Table 2. Measured noise level

Environment	Sound Pressure (dBA)	Environment	Sound Pressure (dBA)
Inside the Subway	80.9	Large supermarket	78.3
Inside the Bus	80.4	Public parks	55.1
Subway Platform	85.7	Office	61.2
Roadside	77.9		

3.2 Frequency analysis of noise environment

We have analyzed the data recorded at the roadside among various noise environments. Figure 3 shows the spectral analysis for roadside sounds. As shown in Fig. 3, most of the energy is concentrated in the low-frequency band of less than 2 kHz. As the frequency increases, the noise energy tends to decrease. In particular, this frequency analysis characteristic has a large influence on the band where information is transmitted through conversation, so that a low signal to noise ratio corresponding to a low frequency is obtained. Furthermore, when these noise signals are mixed with speech, the sharpness of the speech signal is degraded, making it difficult for people to recognize the exact contents. Because the first and second formant frequencies are mainly present at less than 2 kHz, mixing of noise in this band causes a perceptual error to people. In other words, low frequency noise damages the low formant information.

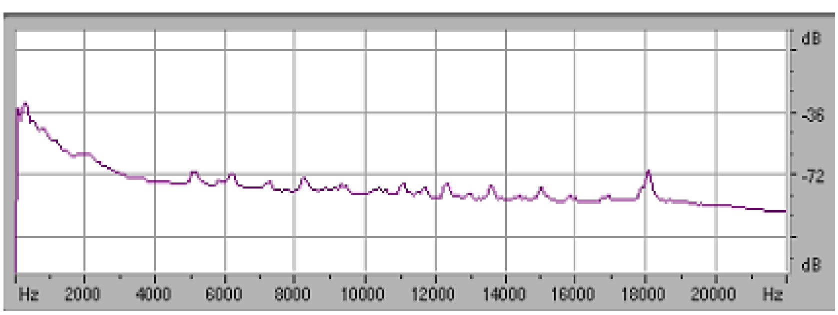

Figure 3. Spectrum of roadside signal

3.3 Sound pressure characteristics of the mobile phone receiver

We did not measure all kinds of mobile device output SPL (Sound Pressure level). However, it was conducted at the highest level of SPL from mobile phone handsets as per the Occupational Safety and Health Administration, and quoted in the 2007 and 2012 studies. The actual measured maximum SPL is more than 110dB of sound from a mobile device. Mobile equipment manufacturers plan to keep mobile phone volume above 100dB or even higher.

Figure 4 is a human auditory graph from the Institute of Occupational Safety and Health. An important point is the damage hazard limits around the 2kHz band, and that mobile devices make more than 88dB of sound that can harm people's hearing [8].

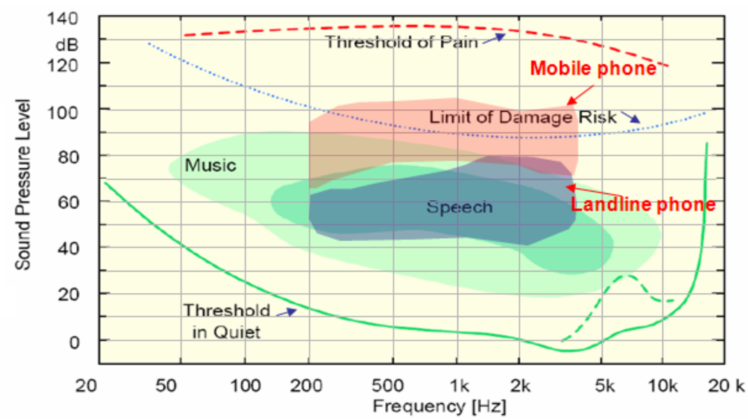

Figure 4. Environments of Mobile phone usage[8]

4. The experiment and the result

4.1 Experiments method

We did not directly measure the noise and the sound volume of portable devices, due to a possible lack of objectivity for such measured results, as they may differ according to the repeatability of the situation, the person and the situation. Instead we experimented by simulating the state of each kind of noise condition for the experiment. That is, the experimenter used the SNR to determine the appropriate SPL of the portable device in a simulated noise condition, calculate the sound volume in the noisy environment and the sound device, and used this data. The simulation was conducted in an anechoic room using a full range monitor speaker to construct variable noise conditions. For objectivity, we used 20 healthy people without hearing loss or auditory illness. We repeated the experiment five times and evaluated the average value for each person. The test sound that we used was a weather broadcast in Korea.

4.2 The result of experiment

Table 3 represents the results of SNR, that is the mobile phone sound levels to noise levels. The experiment results show that the average value of SNR is around 20dB. However the average SNR in more noisy conditions is 18dB.. A mobile phone speaker makes the average sound pressure approximately 100dB, the situation on the roadside and inside a bus. All testers wished to increase the sound of the phone when they were in noisy conditions, and some of them also covered their opposite ear to reduce noise.

Table 3. Experiment result of SNR

Environment	Sound Pressure (dBA)	Environment	Sound Pressure (dBA)
Inside the Subway	17.4	Large supermarket	18.2
Inside the Bus	16.2	Public parks	25.3
Subway Platform	17.8	Office	25.1
Roadside	19.7		

Table 4 represents the results of the sound pressure levels for the mobile devices. The maximum sound level was set to simulate a subway platform. The experiment results show the average pressure for all noise conditions of the mobile phones was 98dB w. The noisiest situation was the subway platform, which also recorded the highest sound pressure level of 103dB.

Table 4. Experiment result of sound pressure level

Environment	Sound Pressure (dBA)	Environment	Sound Pressure (dBA)
Inside the Subway	98.3	Large supermarket	96.5
Inside the Bus	96.6	Public parks	80.4
Subway Platform	103.5	Office	86.3
Roadside	97.6		

5. Conclusion

In this paper, we studied a proper SPL and SNR to use portable IT device. We experimented on mobile IT equipment environment noise conditions and also measured the SPL and the SNR in those noise conditions. From previous studies, we knew that there is a need for SNR to be greater than15dB to facilitate clear listening to information avoiding noise, and that when people were exposed to loud noise that they may suffer from early hearing loss. Despite the fact, that when using a mobile IT device if headset volume is set to more than 90dB hearing difficulties may result, most people exceed this sound level when using such portable devices. We conclude that people set such high volume levels because the noise environment disturbs sound signal frequency on headphones. Additionally, as users want to conduct clear conversations over their mobile devices, they keep the SNR around 20dB. This is critical and potentially very dangerous. Setting the volume of a headset to more than 100dB can cause hearing loss.

People use mobile devices constantly and ubiquitously, but seem to have little concern with potential hearing loss. However, a high SPL (volume) for a mobile device is dangerous to hearing. In order to prevent damage to hearing we strongly suggest that volume (SPL) is set to proper levels, and that people use their devices less in noisy environments. Furthermore, regulations for noise prevention should be expanded. Finally, further studies about active noise reduction on portable IT devices are also needed.

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