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Implementation of Digital Hearing Aid Using Bluetooth Audio Digital Signal Processor

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Abstract

The sound we hear is transmitted through the atmosphere. However, both the sound we want to hear and the surrounding sound are mixed, and noise is generated, and the sound is not clearly transmitted due to factors such as distance. In particular, in closed spaces like buildings, it is often difficult to hear sounds from outside because of the sound of reflection. People with hearing impairments, such as the elderly and the deaf, have a hard time hearing the sounds they want to hear. Thus, we are developing a hearing aid that can detect radio waves. To this end, we propose the development of a hearing aid that uses FM radio and Bluetooth. These devices are expected to be useful not only for the elderly and the deaf but also in situations where information is transmitted to a large number of people, such as students and tourists, in a large space. The main purpose of this device is to enable users to hear sound correctly without blind spots.

Keywords: *Difficulty in Hearing, Hearing Aid, Hearing Impairment, Bluetooth, Audio DSP, Noise, Frequency, Audio Frequency Amplifier.*

1. Introduction

A hearing impairment refers to a condition that makes it difficult to hear due to obstacles in the hearing recognition procedures from the outer ear to the cerebrum. In general, the sound recognition process is as follows. First, when the sound wave in the air vibrates the eardrum from the outside through the outer ear, this vibration is amplified as it passes through the ossicles behind it. The amplified sound wave enters the inner ear through the oval window and causes a vibration. This vibration is converted into electric energy in the cortical organ and reaches the cerebrum through the auditory nerve. If any of these components are not working properly, a person will not be able to hear normally.

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Hearing impairments can be classified based on where the disorder occurs. If there is damage to the pathway from the outer ear to the middle ear, it is called conductive hearing loss. When there is an abnormality of the inner ear and the auditory nerve system, it is called sensorineural hearing loss. They are also classified according to the state of hearing. A state in which communication is possible to some extent without a hearing aid is called hard of hearing. Deaf mutism is defined as a state in which it is impossible to communicate at all [1]. In addition, the increase in the number of elderly people in Korea is expected to increase the degree of senile hearing loss, and it is known that the hearing aid market is growing every year. Finally, the number of patients suffering from noise-induced hearing loss due to noise from earphones and the surrounding environment is increasing, and the social loss due to this hearing loss is increasing [2].

The global market for hearing aids was estimated at $7.77 billion in 2013 and is expected to increase to $12.4 billion by 2020. As of 2014, 82.5% of the domestic market was dominated by foreign companies [3]. This study was designed to integrate broadcasting systems with hearing aids to facilitate marketability. This is because it is possible to listen to non-hearing-impaired in-house broadcasting by using this device, thus expanding usability for education and events. The broadcasting system used the FM system to enable clearer hear regardless of the surrounding noise or location. In addition, Bluetooth was applied to enable interoperability with mobile devices as well as hearing aids and cochlear implants.

2. Related works

2.1 Hearing impairment

The structure of the ear is generally divided into the outer ear, middle ear, and inner ear. The outer ear consists of a pinna and an ear canal and is responsible for delivering sound from the outside to the middle ear. The middle ear consists of the eardrum, ossicles, Eustachian tube, oval window, and round window. When a sound is delivered from the outer ear, the eardrum vibrates, and the ossicles transform the sound into a mechanical motion and transmit it to the inner ear. The inner ear consists of the cochlea, vestibule, semicircular canals, and auditory nerves. The inner ear converts the mechanical waves delivered from the middle ear to electrical signals.

Hearing impairment is particularly lethal during infancy and has a negative impact on language acquisition and intelligence development. Conductive hearing loss can be corrected by surgical methods or artificial organs, but it is difficult to recover after sensory nerve damage. The types of hearing impairment can be classified into conductive hearing loss, sensorineural hearing loss, and noise deafness. Conductive hearing loss is characterized by hearing loss caused by abnormalities in the ear or middle ear, and the resulting hearing loss differs for different sound frequencies. Therefore, the main solution is to resolve the hearing loss using surgical procedures or ancillary devices. Hearing loss caused by abnormalities in the area next to the inner ear is called sensorineural hearing loss. If this part is damaged, it is difficult to recover. Hearing loss in this part occurs by the recruitment phenomenon. Assuming that the sound will grow larger, a recruitment phenomenon causes a sound to crack or vibrate from a certain point. Noise deafness is a disorder mainly caused by working in noisy places or by using earphones at excessive volume [4].

2.2 Hearing aids

Hearing aids are devices that are used to enhance the hearing of the deaf. Early hearing aids had a conical shape and only functioned to concentrate the sound at one point. The invention of the telephone made it possible to electrically amplify sound, and hearing aids became small enough to fit into the ear. They can be classified into analog and digital hearing aids depending on the signal processing method.

As shown in Figure 1, the basic structure of a hearing aid consists of a transducer, amplifier, and battery. Digital hearing aids include microphones, telecoils, and receivers. According to [5], hearing aids can be classified into box-type, Receiver in the Canal (RIC), Behind the Ear (BTE), In the Ear (IET), In the Canal (ITC), and Completely in the Canal (CIC). Generally, box-type, RIC, and BTE are larger than the other types of hearing aids, so their battery capacity is higher, making them more advantageous for sound amplification. In the case of the IET type, its advantage is that it is not seen from the outside, but it cannot be worn if there is inflammation in the ear, and it causes an occlusion effect.

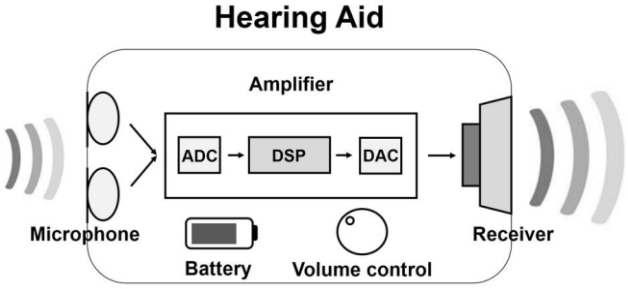

Figure 1. Diagram of digital hearing aid [6]

ADC, Analog digital converter; DSP, digital signal processor; DAC. Digital analog converter

3. Digital hearing aid systems

If users want to hear high-quality audio from a hearing aid, they must first amplify the audio signal they want to hear in noisy audio. In actual use, the sound is always contaminated by ambient noise. In the case of the general public, the sound that can be heard in the noise is separated and understood. However, people with hearing impairments cannot hear for various reasons. Therefore, the role of hearing aids for those with impaired hearing is to remove the noise in the noise sound, amplify the voice signal to be heard, and improve the strength of this signal. In addition, even people without hearing impairments who need to communicate more precisely and efficiently can use this method, such as people involved in extreme work environments or military operations or those who use speech recognition technology or speaker recognition performance using human–machine interaction in various smart devices or medical devices. It can also be used in audio equipment, such as headsets and digital hearing aids, to suppress background noise and improve sound quality [7][8].

3.1 Bluetooth

The Bluetooth specification is a standard for sending and receiving data using radio waves without connecting cables. Originally developed by Erics in 1994, it is now available up to version 4.2, and the latest version has been developed to be available in a low-power and narrow range. Therefore, the Bluetooth Special Interest Group (SIG) wants to designate it as one of the IoT standards. This technology is available in almost every region and can be used with a variety of computer and communications devices [9].

3.2 Proposed device

The functions of the proposed device are as follows.

First, implement the hands-free (HFP) function and audio listening (A2DP) function by connecting with a

smartphone using BT's sync function. It implements the hearing aid function by applying BT's mic input and internal DSP function. Then, connect to the audio output of the repeater using a neckloop. Use the T-mode of general hearing aids wirelessly. One neckloop company has developed a product that has a dedicated mic function and call function to avoid inconveniences and improve connections with smartphones.

Second, connect the BT signal to the BT hearing aid using the BT source function and transmit the received FM signal. It receives the signal via the FM receiver and transmits it wirelessly via BT. Afterward, the signal is transmitted directly to the hearing aid to enable the user to listen to public broadcasting without surrounding noise. The output of the hearing aid amplifies the signal to suit individual hearing impairments. To do this, we use a dedicated earset for the amplified output signal.

Third, enhancement the hearing aid function using BT's audio DSP function. The implementation of the hearing aid function through BT's audio DSP generally causes delay when voice amplification is performed. To solve this problem, it is necessary to control the delay through DSP program development. It also uses auto gain control (AGC) to reduce background noise and protect users' hearing. This function delays the sound signal by analyzing the surrounding environment and voice speed. The AGC reduces ambient noise and makes listening more comfortable.

3.3 VCP System

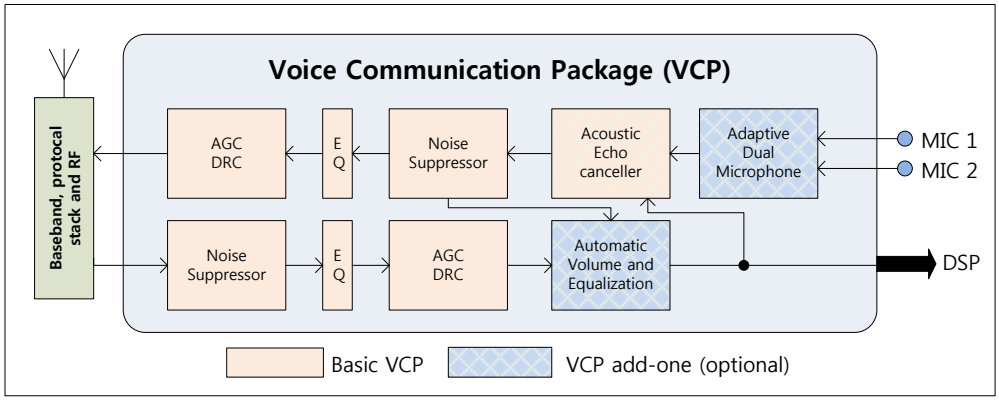

Figure 2. VCP System

This system improves the sound quality. As shown in Figure 2, the functions of the proposed device are as follows.

- Adaptive Dual Microphone: (Optional) Attenuates all types of noises for near field and far field cases
- Acoustic Echo canceller: Eliminates acoustic echoes ensuring full-duplex communication
- Nose Suppressor: Suppresses stationary and transient noises (traffic, engine, etc)
- Automatic Gain Control: AGC equalizes possible changes in signal levels
- Dynamic Range Compressor: Improves speech intelligibility, decreases loudspeaker distortions
- Volume and Equalization Control: Automatically amplifies and equalizes loudspeaker signal according to the environmental noise
- Frequency equalizers: 8Band equalizers for precise microphone and earphone equalization

3.4 System configuration

As shown in Figure 3, it receives the channel of the dedicated hearing aid frequency band transmitted from the transmitter and outputs it to audio through BT's DSP in sync mode. Neckloop can be connected to

the proposed device, and T-mode can be connected to the hearing aid wirelessly. In addition, users can use the built-in mic to use the hands-free function after connecting with a smartphone. At this time, the listener listens to the sound using the hearing aid or the earset connected to the device.

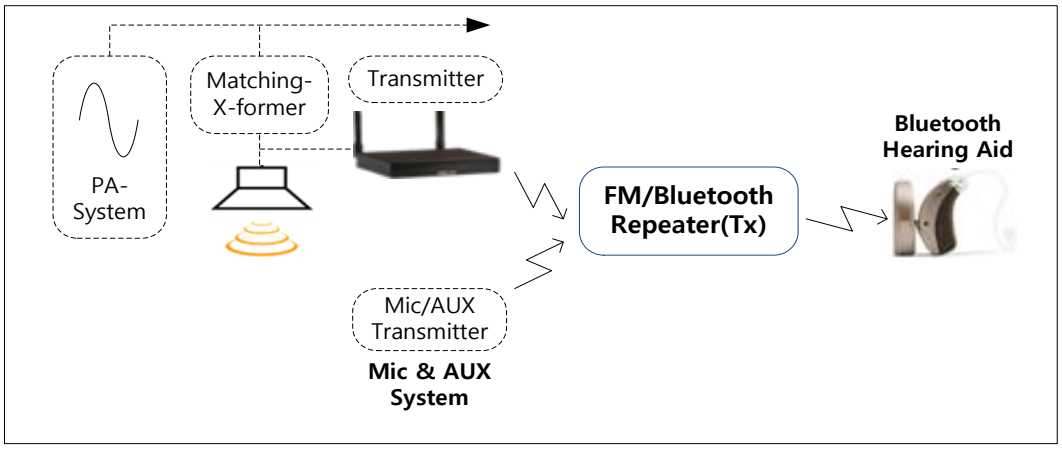

Figure 3. FM Bluetooth repeater system

3.5 Developed system

The implemented system is as follows.

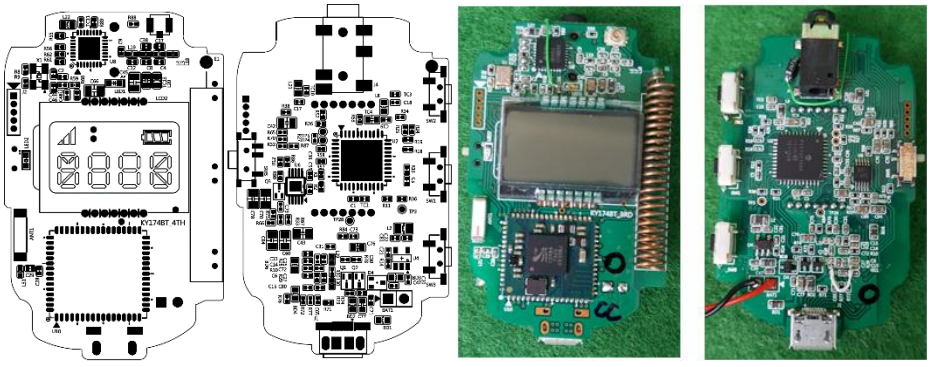

Figure 4. Printed circuit board of implemented system

The above system has been certified and will be contribute to public institutions and other place after field testing.

Figure 5. Developed system

4. Conclusion

The proposed hearing aid offers an advanced design, efficiency, and economy and can provide more choice to the deaf by adding a broadcasting listening function. The hearing impaired can also connect it to their smartphones. This feature makes hearing aids more convenient and natural. Since it has the in-house broadcasting listening function using FM, it can be used for other purposes, and it is expected to be put to practical use. However, two things will be needed in future. First, the function and reliability of audio output to relay function devices, such as function tests and neckloops, will need to be secured. Second, the use of hearing aids by Bluetooth should continue to be improved.

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