A Study on Effective Amplification Gain in Cochlea Dead Region with Word Recognition Score

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Abstract

When the cochlea in the inner ear hair cell has functional problems, a sensorineural hearing loss (SNHL) occurs, and we called 'cochlea dead region'. Cochlea dead region is that no (or very few) functioning in inner hair cell or neurons. In this paper, we tested word recognition score (WRS) to know an effective amplification of hearing aids with different location of dead region and gain (dB). The test signal was mixed with white and babble noise (SNR = 0 dB) for eight people who had normal hearing ability. We divided three conditions by location of dead region in low, middle and high frequency. Low frequency dead region was defined under 1100Hz in frequency. Middle frequency dead region was between 1350Hz and 2700Hz. High frequency dead region was over 3100Hz. In addition, gain was various such as 6 dB, 11.5 dB and 14.5 dB in each dead region. The results were different by locations and gains of dead region. Firstly, the result of WRS with middle frequency and high frequency dead region were higher than low frequency dead region. Secondly, the result of WRS was high score, when low gain in low frequency dead region, high gain in middle and high frequency dead region.

Keywords: *Cochlea dead region, hearing aids, WRS, amplification gain*

1. Introduction

The hearing implement is sort into conductive hearing loss and sensorineural hearing loss, and sensorineural hearing loss is sort into sensory hearing loss, neural hearing loss and central hearing loss [1]. When it is taken place sensory hearing loss, the delivery system of auditory signal has problem in inner ear or the central nervous system [2, 3]. the sensorineural hearing loss is become known to damage with growing old, the exposure of loud noise, drugs and other reasons in inner hair cell and outer hair cell of cochlea [4].

B. J. Moore (2001) called 'cochlea dead region', there is no gain of amplification in a certain frequency [5]. It is processing in research of dead region; the patients with high frequency dead region are more than with low frequency dead region.

Cochlea dead region may be complete loss of function of inner hair cells over a certain region of cochlea. In addition, this region cannot transmit some information about selective frequency. Because patients who have difficult in hearing are moderately severe hearing loss, high frequency signal is generate to diagnose dead region at present [6].

In order to diagnose dead regions, high frequency pure tone is generated, and detect where dead regions are [7].

2. Method and Experiment

2.1 Conventional Fitting Method on Hearing Aid

Fitting for the hearing impaired with dead region has to different from the hearing impaired without dead region [8]. However most of the researches are focused on the way of diagnosing dead region as hearing loss and perceptual ability of the hearing impaired. A typical method is threshold equalizing noise (TEN) test. This test is detecting hearing loss using an audiometer that makes pure tones from frequency of 500Hz to 4000Hz. However they did not suggest the best fitting method on hearing aid.

In the researches of Vickers (2001) and Baer (2002), the amplification of hearing aid was a pointless, because the hearing ability near dead region at high frequency had 70% of normal hearing [9, 10].

The best fitting method for hearing impaired with dead region is necessary to improve performance of hearing aid. In spite of a lot of suggestion of fitting on hearing aid for the impaired with dead region, it has not decided the best fitting method. The reason is that location and bandwidth of dead region and hearing loss is various in individual, so perception of auditory signal is different.

In this paper, we designed filter, similar with auditory filter, for low, mid and high frequency dead regions. And then, various amplification gains were fitted in each dead region. In other words, we studied about an influence by locations and amplification gains of dead region.

2.2 Method

In this paper, we divided dead region by low, mid and high frequency dead region. Low frequency dead region was lower than 1100Hz, mid frequency dead region was from 1350Hz to 2700Hz, and high frequency dead region was above 3100Hz. The sampling rate was 1600Hz for WRS test signal.

Subjects were 8 people, the age were between 26 and 29. They had normal hearing ability and usually talked without any problem. We designed mel-filter bank, which was similar to auditory filter. Mel filter bank is defined as (1).

$$(\mathrm{k}) \begin{cases} 0 \quad \mathrm{if\,k} < \mathrm{f(m-1)}\, and\ if\ k > f(m+1) \\ \dfrac{\mathrm{k-f(m-1)}}{\mathrm{f(m)}-f(m-1)}\ if\ f(m-1) \le k \le f(m) \\ \dfrac{\mathrm{f(m+1)-k}}{\mathrm{f(m+1)}-f(m)}\ if\ f(m) < k \le f(m+1) \end{cases} \qquad (1)$$

Where f(m) is the center frequency. Mel filter bank is chosen for this purpose because it closely resembles the human cochlea in characteristics. In Mel filter bank, just like the human cochlea, the filter characteristics are linear till 1 kHz and logarithmic above 1 kHz [11]. Figure 1 shows the overlapping triangular mel filter bank and the number of filter is 35 [12].

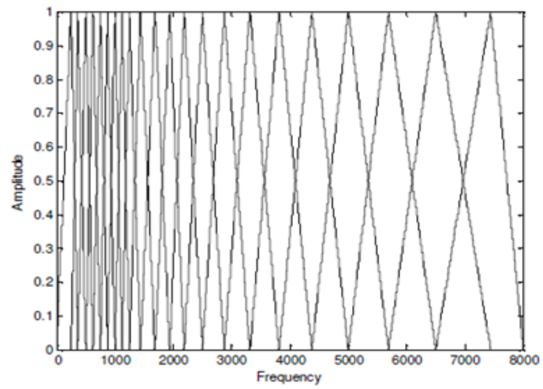

Figure 1. Overlapping Triangular Mel Filter Banks. The Total Number of Filters was 35.

Figure 2 was the algorism of adapted filter. In order to adapt filtering, 512 sampled data in a flame was transformed by fast fourier transform (FFT). Dead region and others are different amplification gain in frequency domain. After amplification, components were transformed by inverse fourier transform (IFFT.)

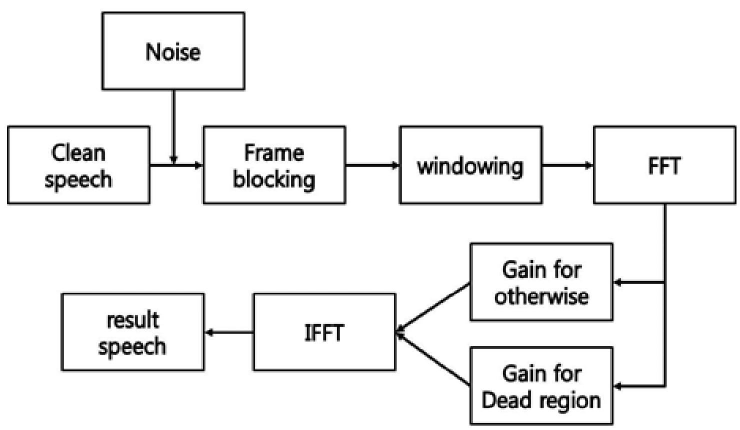

Figure 2. Block Diagram of Filter Processing

2.3 Experiment

As we divided three cases of dead region in different frequency, the amplification gain of each dead region in was zero, because dead region has complete loss of function. The amplification gains of other frequencies were half gain. The half gain lead to 6 dB down. We used two type of noise, babble noise and white noise (SNR=0dB). We evaluated signal distortion by word recognition score (WRS) in various location and gains of dead region with noise.

WRS was consisted 25 words which was a syllable, and the result was expressed as a percentage. Each word is the same sound level, dead region was divided into low, mid and high frequency, the amplification gains were 14.5dB, 11.5dB and 6dB and we tested in white noise and babble noise. Table 1 is set of test signal.

Table 1. The Consist of Test

Case	Noise	Frequency of dead region	Amplification of dead region
1	no noise / no dead region		
2	Babble noise	no dead region	
3		Low frequency	14.5 dB
4			11.5 dB
5			6 dB
6		Middle frequency	14.5 dB
7			11.5 dB
8			6 dB
9		High frequency	14.5 dB
10			11.5 dB
11			6 dB
12	White noise	no dead region	
13		Low frequency	14.5 dB
14			11.5 dB
15			6 dB
16		Middle frequency	14.5 dB
17			11.5 dB
18			6 dB
19		High frequency	14.5 dB
20			11.5 dB
21			6 dB

3. Result

3.1 The Result of WRS

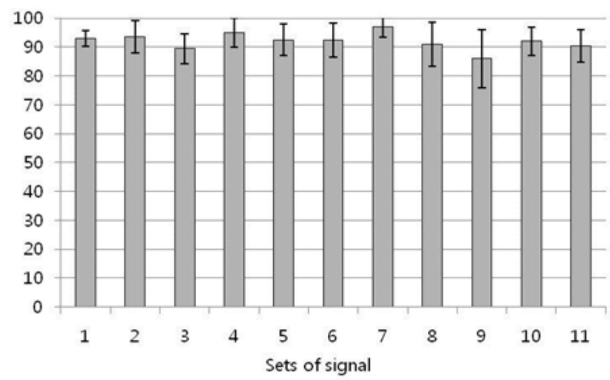

Figure 3. The Graph of WRS with or without Noise

The result of test at signal without noise was a standard value for test of dead region. Figure 3 expressed a relative score of each sound signal of Table 1.

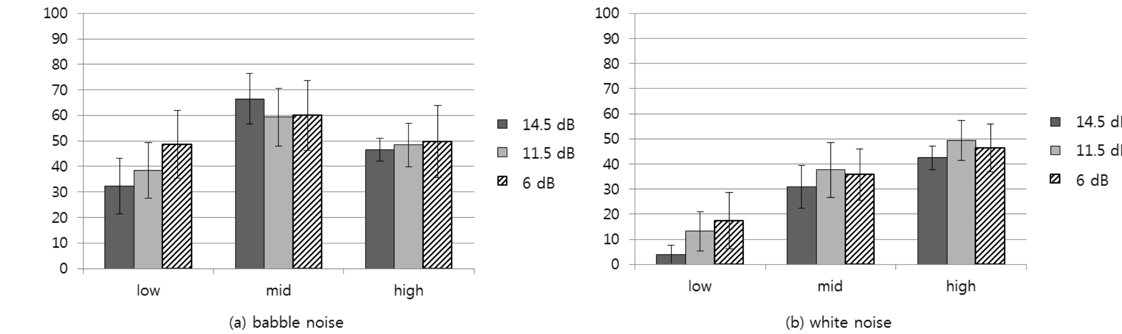

Figure 4. The Graph of WRS in Different Dead Regions;
(a) is Signal with Babble Noise and (b) is Signal with White Noise

WRS results of low frequency dead region was lower than mid and high frequency dead region in Figure 4, because most information of speech signal was in low frequency, the hearing impaired with low frequency dead region couldn't be affected on hearing aid. In other words, auditory signal was damaged a lot in low frequency dead region.

WRS results of mid frequency and high frequency dead regions were different as the types of noise. In case of high frequency dead region, the WRS result was lower than other frequency dead regions with white noise, but difference of score between them was not big with babble noise. The damage of auditory signal in high frequency dead region was slighter than other frequency dead regions

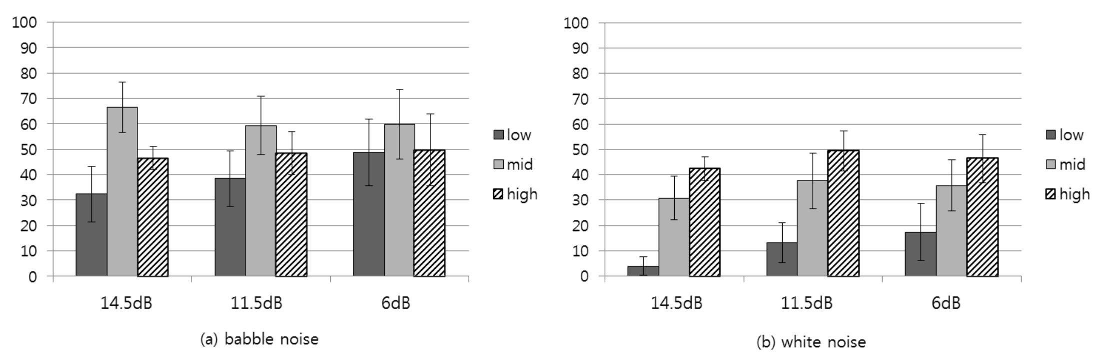

Figure 5. The Graph of WRS in Different Dead Region Gains;
(a) is Signal with Babble Noise and (b) is Signal with White Noise

Figure 5 showed the average WRS results of 8 people with various amplification gains. In the case of low frequency dead region, the result of WRS was low as high amplification gain. When the amplification gain was 6dB, the result of WRS was the best. On the other hand, the result was different when dead region was in mid and high frequency. The amplification gain of 11.5dB was the best in white noise and the result was not correlated in babble. The reason was that inner hair cell could not transmit some simulation at big amplification gain.

4. Conclusion

In this paper, I classified dead region by frequency band and amplified various gain in dead region to see the different recognition of words and distortion of auditory signal for the impaired with dead region. When dead region was at low frequency, the result of WRS at 5dB gain was 14.9 ± 2.1 point higher than 14.5dB gain. This result cause that most information of auditory signal could not be transmitted to inner hair cells because it distorted in low frequency.

When dead region is in middle and high frequency, the result of WRS was significantly higher than dead region at low frequency. This result meant that distortion of auditory signal was getting lower as higher frequency dead region. In other words, the hearing aid was less effective for the hearing impaired with low frequency dead region than mid and high frequency dead region. As dead region was higher frequency, recognition of auditory signal was better.

In conclusion, the amplification of gain in low frequency dead region was the same as other frequency band to minimize the distortion of auditory signal. If dead region was high frequency band, hearing aid fitting had to be considered bandwidth of dead region and amplification gains for hearing loss.

Acknowledgements

This work was supported by Key Research Institute Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology(2011-0018394).

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