Hearing-Loss Compensation in a Telephone System

Feifei Xiong[1], Dirk Schneider[1], Stefan Goetze[1], Stephan Ewert[2], Thomas Rohdenburg[1], Jens-E. Appell[1]

[1] *Fraunhofer IDMT, Project group Hearing-, Speech-, and Audio Technology, Oldenburg, Email: feifei.xiong@idmt.fraunhofer.de*

[2] *Carl-von-Ossietzky University of Oldenburg, Medical Physics*

Introduction

Hearing loss is amongst the most prevalent disabilities, which severely hinder normal speech communication for hearing impaired persons. Although digital hearing aids have been developed for several years, only the minority of hearing impaired persons use hearing aids due to different reasons. One reason is lack of the convenience for the users particularly for telephone conversations, which is an important aspect of daily communication. To tackle this problem, a personalized and adaptable telephone system incorporating compensation strategies for individual hearing loss is described in this contribution. Multiband dynamic compression was used to compensate for hearing loss. Ten presets were defined based on ISO7029 [1], as well as the NAL-R and FIG6 formula [2] to specify the gain and compression ratios respectively. The effectiveness of the proposed system was evaluated by hearing aid users who were asked to compare the adjusted telephone system after selecting the preferred preset with a standard telephone system but wearing their own hearing aid. The results show that the integrated telephone system was able to improve the perceived sound quality and intelligibility as well as the satisfaction for the hearing impaired users in this specific listening condition.

Hearing Support Technique

Advanced research and development on hearing aid technologies have been carried out in the past years in order to counteract hearing impairment and to allow hearing impaired people to participate normal speech communication. However, supporting technologies improving convenience for normal telephone calls are still need to be improved for hearing impaired persons. Even though digital hearing aids are worn during the telephone communication, a Net Satisfaction Score (NSS= %satisfied − %dissatisfied) of 23% [3] indicates that still a large potential to improve the satisfaction for this type of conversation exists. This work aims at designing a practical fitting strategy specifically for the telephone application on the basis of individual hearing support techniques.

Motivated by the development of multi-band dynamic compression techniques, a typical three-channel hearing support algorithm [4, 5] was selected to compensate for the individual hearing loss. In a typical hearing aid, the I/O characteristic of the compressor is adjusted on the basis of the individual hearing loss which is unknown in the current telephone system application. To tackle this, a preset concept was introduced here to achieve a practical adaptation for the hearing support in the telephone system. The presets are based on the average age related hearing threshold [1]. In order to maximize speech intelligibility, the NAL-R formula [2] was applied to determine REIG (real-ear insertion gain) for normal speech loudness levels. Furthermore, motivated by meeting loudness requirements, the FIG6 procedure was integrated to calculate the frequency-dependent compression ratios.

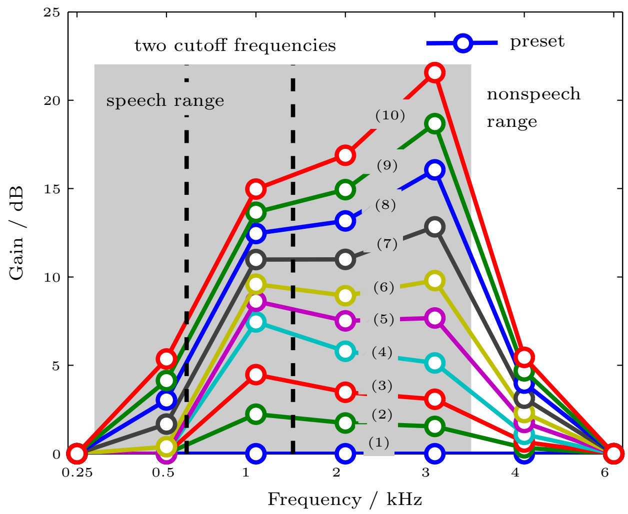

Figure 1: Presets defined by [1], NAL-R and FIG6 at the frequency range of telephone speech signal, i.e. 300 to 3400 Hz; the two cutoff frequencies between the compressor bands were 612 Hz and 1414 Hz.

Figure 1 shows the insertion gain of the ten presets over frequency. The target was to cover typical age-related hearing losses. In addition, the ten presets take the specific hardware properties of the telephone handset into account, e.g., frequency response and dynamic range (based on a distortion measure), to guarantee a high-quality output from the handset.

Experimental Procedure

Two experiments were carried out in order to obtain the subjective feedback on the hearing support technique embedded in the telephone device. One was a fitting test where the user should select the desired preset from the telephone interface, i.e. number 0 to 9, representing the ten presets. The second experiment was a comparison to determine whether the hearing support from the telephone offered an advantage over the situation when the user used his or her hearing aid which was fitted individually. In addition, a questionnaire was filled out by each user while making the decisions to collect subjective opinions and announcements.

Eight hearing aid users (five male and three female; age between 25 to 76 years) participated in the experiment. Two identical standard telephone devices (Allnet AL-L7950) were used. Three test speech stimuli (one male voice and two female voices; each of 90 seconds) were recorded through the handset microphone of one telephone. They were presented to the subjects by the other telephone handset in a sound insulated room. A quiet environment was chosen to provide best conditions for both presentation techniques. Both left and right ear were tested. Furthermore, in order to ensure an appropriate loudness of the conversation speech, 83.3 dB SPL [6] from the handset loudspeaker was chosen as a reference calibration value for the unprocessed signal, which was measured with a KEMAR dummy head.

Results

Table 1: Results of the experiment from 8 hearing aid users.

Subject (Gender)	Ear	PTA / dB	Mean Preset	Beneficial or not
1(male)	left	43	1	no
	right	53	4	yes
2(male)	left	43	4	yes
	right	41	2	yes
3(female)	left	23	3	yes
	right	18	3	yes
4(male)	left	55	5	yes
	right	56	5	yes
5(female)	left	38	1	no
	right	30	1	no
6(male)	left	22	3	no
	right	25	1	no
7(male)	left	37	6	yes
	right	33	6	yes
8(female)	left	31	1	no
	right	38	1	no

The subjective results of the experiment are shown in Table 1. The individual audiogram data is expressed here in terms of Pure Tone Average (PTA) at 0.5, 1, 2 kHz. The mean preset for each subject (averaged across the preset selections for all three stimuli) is given in column 'Mean Preset'. The variance of the preferred presets across the three stimuli was not larger than 2. It is shown that individual audiogram data is a valuable but not crucial factor to define an appropriate preset for individual user with hearing loss from column 'PTA'. The last column of Table 1 indicates the assessment of the users whether the telephone system with the selected preset was preferred over the situation with regular telephone and individual hearing aid. 57% of the hearing impaired ears preferred the telephone system with incorporated hearing support instead of their own individually fitted hearing aid for the tested telephone situation. Additionally, 15% of the subjects preferring the hearing supportive telephone reported that it performed nearly as good as their hearing aids from the questionnaire. Furthermore, 39% argued that they usually preferred unaided telephoning over the use of their hearing aids, which indicates difficulties with using the telephone in combination with their individually fitted hearing aids. This can be partly explained by the coupling effects between the telephone handset and hearing aid, e.g. Behind the Ear (BTE) hearing aids or closed fitting type. On the other hand, 43% pronounced that the hearing supportive telephone system could not provide them any benefit, even though only 50% of them found that their hearing aids helped them when participating in a telephone communication. This shows that the current hearing aids only help a small parentage of the hearing impaired population sufficiently for the telephone conversation.

Discussion, Conclusion and Outlook

In this paper, an individually adaptive hearing support technique in a telephone system was introduced and tested with hearing impaired subjects. The experimental results indicate that people with moderate to severe hearing loss in general benefit from incorporating individualized hearing support strategies in telephone devices. More specifically, under the optimal experimental conditions regarding to loudness and speech intelligibility, we assume that the outstanding advantages from the proposed system are not obvious to experience for mild hearing impaired users. However, this assumption from our first experiments needs to be further investigated under more realistic conditions, e.g. using different input speech presentation levels and in noisy acoustic conditions or with multiple competing talkers. Furthermore, a higher demand for supportive signal processing is expected if more background noise as well as the circuit noise aroused from the telephone connection is present. For the sake of ease, the amount of the presets could be reduced and the preset selection can be fine-tuned more efficiently. Such experiments are subject to future work.

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