TELEPHONE AND HEARING IMPAIRED – NEW APPROACHES FOR INCREASING THE TELEPHONE SPEECH QUALITY FOR HEARING IMPAIRED USERS

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Abstract: The future age structure of industrialized countries will shift towards elderly, and an average elderly telephone subscriber will face a mild high frequency hearing loss. Hearing impaired telephone users will be one of the major groups of possible subscribers for telephone connection or telephone service vendors. To offer them benefits against existing solutions does not require much effort or special new technologies, but precise knowledge of the needs of this group. Some of these needs are presented in this article and they are based on interviews and lessons learned from tests described in CVHI 2006 contribution (Krebber et al. 2006). Moreover, new approaches, recommendations and the needs of certain standards are discussed in this paper.

Keywords: Hearing impaired, telephone, quality, recommendations

1. Introduction

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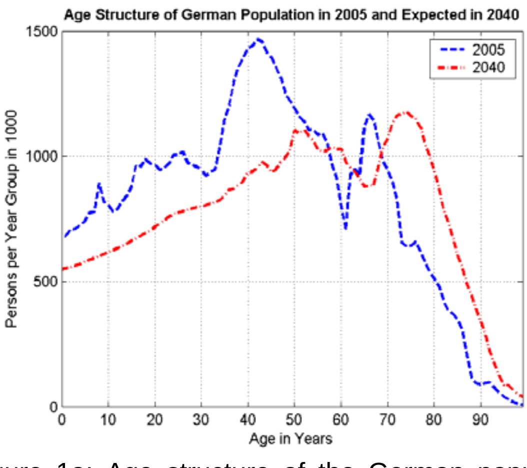

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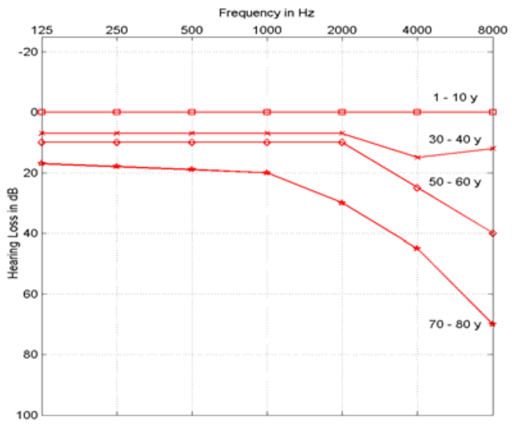

Figure 1a: Age structure of the German population in 2005 and expected 35 years later in 2040 (values according to Statistisches Bundesamt, 2007).
Figure 1b: Permanent threshold shift of an average German female according to age (Fuder 2007).

In the future, we have to face a growing part of hearing impaired (HI) people in the society. There will be shift in the age structure within the next decades as shown in Figure 1a and in Table 1. The majority of the population will not be between 35 and 45 years (2005) but is expected to be between 70 and 80 years (2040).

Age Group	2005	2040
0 - 19	20%	16%
20 - 64	61%	53%
65+	20%	31%

Table 1: Distribution of the German population in 2005 and expected in 2040, grouped by age (values according to Statistisches Bundesamt, 2007).

Moreover, young people are increasingly using personal audio devices, which can damage their sense of hearing, like MP3 players or mobile phones with music playback capabilities. According to the Dresden lifetime dose model of hearing loss most of those people will face a high frequency hearing loss of ski slope type. The permanent threshold shift (PTS) shown in Figure 1b is drawn for the mean lifetime dose of a female person. The model does not cover short impulsive sound exposure or hearing loss caused by illness or medication; it only takes long term “continuous” noise into account. From literature it can be found that it may take long time until the HI person realizes and accepts the hearing loss as such (Latzel 2000). Another problem is the “unwillingness“ of changing the environment, just because of negligible hearing loss. From the tests we learned, that this holds also for telephones and telephone equipment.

2. Basic Requirements of Hearing Impaired Subscribers

It turned out that most of the participants with moderate hearing loss (from the tests described in Krebber et al. 2006) did not prefer to use their hearing aid (HA) for telephone calls. Moreover, the HA did not show any benefit for the users. It gave worse results for all tested conditions. This dissatisfaction can be explained mainly by the following items:

2.1 Satisfying quality and connection between the telephone and hearing aid

So far, the existing solutions for improving the terminal telephone equipment are not superior to old telephone handset and the direct acoustic coupling. The telecoil solution is still not found to beat the acoustic coupling, and cheap Bluetooth®-based connections between telephone and HA consume too much power because of the Bluetooth® technology standards. Established solutions like SmartLink® are of high satisfaction, but they seem to be far too expensive to hit the wide mass market.

2.2 Satisfying handling

The usability and the handling of the HA do not meet the demands of many users. Miniature switches at the HA remain sometimes “unusable” because of their size. Many HI users prefer to take the HA out before calling or leave the HA of the telephone ear out completely for a certain period of time, in case they expect to make or to get a phone call. Remote control solutions require that the HI user carries the remote control with him all the time, moreover those systems still remain quite expensive.

2.3 Standards to combine assistive technologies from different vendors

In case of telecommunications there are no defined standards for HI subscribers neither at the terminal equipment (e.g. no sufficient magnetic field from the handset phones) nor at the telephone transmission line itself (e.g. even the amount of speech decoding/encoding algorithms is not restricted).

2.4 Other requirements

These requirements result in either new, open standards for connecting HA technology to further devices, like a telephone (or other audio devices, e.g. public announcement systems) combined with new or updated telephone terminal equipment or hearing-aid-less solutions with extended or renewed telephone terminal equipment. For the time being it seems that for most of the HI users the most feasible way would be an extension of the telephone capabilities, rather than buying a new HA because of costs. But from the interviews done during the experiments (Krebber et al. 2006) it turned out what keeps many of them away of buying a new phone is the fact that

"The old one is not broken!"

So far there seems to be a threshold for many mild and moderate HI subscribers in completely renewing existing telephone equipment. This may go back to several issues:

- Unwillingness to spend money for replacing something what is still working without any failure
- Fear of being confronted with new technology and new user interfaces (Docampo Rama, 2001)

This behaviour leads to the point that the original telephone should stay as some kind of basic device available to the mild or moderate HI telecom user. The solution should be around the old base station, and could be done into two directions as shown in Figure 2. The first approach of additional telephone speech signal processing could be done either hardware-based, between the base station and the handset or within the subscriber line.

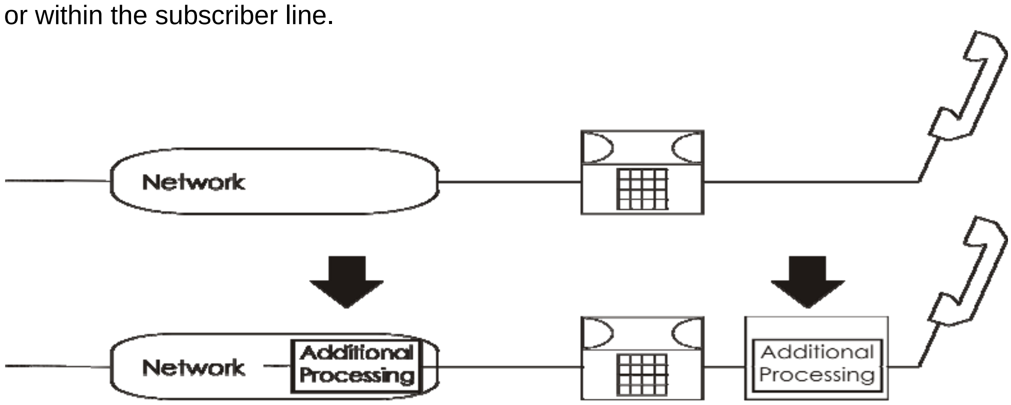

Figure 2: Additional processing positions for speech signal enhancement within a telephone connection.

3. Solutions for Improving Telephone Speech Quality for Hearing Impaired Subscribers

3.1 Updating the telephone terminal equipment

The partial update of the terminal equipment could be done either by inserting an additional signal processing stage between the telephone base station and telephone handset or by replacing the telephone handset with a special HI handset, which includes amplification stages and sometimes additional signal processing stages. This updating is costly for the subscriber and stationary, but it can be done by the user himself. Some technical solutions are already available on the market, some will follow most probably in the near future. The additional processing of the speech signal may cover the following: Frequency-dependent dynamic processing, full bandwidth dynamics and equalizing to increase intelligibility by boosting higher frequencies up to certain extend. Another more sophisticated approach is to transfer the HI subscriber's HA supply into the terminal equipment, and make the HA obsolete for phone calls. These solutions require usually the assistance of the HA vendor to achieve optimum results for the HI subscriber.

3.2 Updating the subscriber line between network and base station

This approach puts the signal processing stages at the edge of the network itself. At the interface between network and subscriber line remains the possibility for additional signal processing for the HI subscriber. As the interfaces (gateways nowadays) are software-based, the updating of the operating system could include additional signal processing software. This would be very cost efficient and would allow also flexible "non-stationary" solutions[1].

Several topologies could be possible. For maximum gain from a telecom line: An automatic gain stage is followed by a compression stage, which in turn is followed by an amplification. This topology allows reducing the dynamics of the speech signal and delivers higher output levels regardless of the input signal level. Another solution with emphasis on higher frequencies is the following scheme: The first stage should be a gain reduction stage to prevent clipping in the following signal processing stages. The next stage is an EQ function according to $\frac{\text{hearing loss}}{2}$ followed by a limiting stage. These two approaches allow ready presets, in case high frequency hearing loss is supposed to be the "standard" form of hearing loss. Even these solutions remain very basic and less sophisticated than some of the terminal equipment extensions, they can offer immediate improvement of quality for the HI subscriber without the need of a HA vendor.

3.3 Updating the subscriber line between network and base station

As already mentioned, the existing solutions for coupling the telephone terminal equipment with the HA do not match all aspects for wide acceptance. So far all coupling solutions come with a major drawback:

- *Acoustic coupling, handset – unaided ear*: To the knowledge of the author, there are not available any telephones with sophisticated signal processing for HI users. So far there are only few telephones with tone and/or volume control on the market, but no (frequency-dependent) dynamic signal processing or user-optimized equalizer settings.
- *Acoustic coupling, handset – hearing aid*: Very seldom preferred, as feedback for in-the-channel HA behind-the-ear HA (caused by a change of the acoustic impedance by bringing the telephone handset close to the HA microphone) and acoustic leakage (caused by too long distance between HA and telephone handset) usually make the *acoustic coupling, handset – unaided ear* superior to the *acoustic coupling, handset – hearing aid*.
- *Inductive coupling, handset – hearing aid*: Many new telephone handsets do not provide a sufficient magnetic field for coupling the HA via the telecoil with the telephone handset. Nowadays special telephones with magnetic fields of 25 – 50 mA/m are available, but not as a standard. Moreover, the HA has to be switched to the telecoil, which some users do not manage because of fiddly control switches. In some countries it may even happen that telecoil programs are not set up for the HA user, even the telecoil is built in the HA. In terms of speech intelligibility, the *inductive coupling* is not superior to the *acoustic coupling, handset - unaided ear* in quiet environments.
- *Inductive coupling, room loop – hearing aid*: This solution requires a certain output from the phone (which is available only at special phones) and a telephone input at the loop amplifier.
- *Radio-frequency-based coupling, telephone – hearing aid*: As already explained, neither the Bluetooth®-based solution, nor SmartLink® did establish a standard.

To overcome all these drawbacks concerning the coupling would be using a standard radio frequency-based (RF) connection between the HA and additional audio devices like telephone handset.

[1] In the latest office concepts it may happen, that there is no certain place for the employee anymore, just his personal locker. This means there is no more his personal telephone either. Usually the employee simply registers at a certain desk, and all necessary personal connections will be routed to this desk, like his personal telephone number. The gateway-based solution would offer the HI employee to use always his personal signal processing for his phone, regardless of his working place.

4. Required Standards and Recommendations for Improving Telephone Speech Quality for Hearing Impaired Subscribers

4.1 Telephone connections

The partial improvement of the telephone terminal equipment would need a standard interface for connecting the base station and the handset. Many modern telephones already use the 4P4C connectors (trade name RJ10 or RJ14) to connect handset and base station via a 4-wire link. One example connection is shown in Figure 3. These standard connectors allow inserting new devices between the base station and the handset or they allow a complete exchange of the handset according to the subscriber's needs. Sometimes exchanging the handset is not possible, as it may host some special features like a small magnet for switching a reed contact inside the phone, which replaces the handset detection switch at the base station.

Unfortunately there is no registered jack code for the connection between handset and telephone base station. A standardized connection with a standardized wiring scheme and standardized levels would allow a universal "additional processing equipment" between the base station and the handset. We recommend the registered jack code for 4P4C connectors for handset – base-station connection as follows:

- Pin 1: Microphone +
- Pin 2: Phones
- Pin 3: Phones
- Pin 4: Microphone – (GND)

Figure 3: RJ10 connection at the base station, RJ10 plug and RJ10 connection at the handset.

4.2 Hearing aid link

A standard connection would be of use also for mobile phones. Here the situation is even worse, as every manufacturer can change the type of connectors even within their own portfolio. One solution would be to provide a standard interface, e.g. mini USB, which would allow standard adaptors for all mobile phones. With these adaptors it would be possible to use a "standard" USB handset with a mobile phone. Even this solution may look clumsy at the mobile phone, it would give much benefit to the HA user, as the mobile phone with its interfering RF sender could be packed to the trouser pocket or to the backpack, far away of the HA.

However, the personal HA remains the best hearing assistive technology. The goal should be to provide a widely accepted standard for preparing or equipping devices with standard HA connection technology. So far, the existing technology is not satisfying. The solution would be to equip mobile phones with a hearing aid link inside. This link should be RF-based as the telecoil solution is very sensitive to interfering magnetic fields. The solution could be the RF-based wireless connection according to the "Body Area Network" (BAN) specifications provided by HearCom SP4 (www.hearcom.eu). Another option would be to design an extension with BAN technology for HA connection *prepared* mobile phone series. The same could work for DECT (Digital Enhanced Cordless Telecommunications) phones with a hearing aid link inside. This would be a suitable solution for making the DECT technology also available for HA users.

4.3 Network-based signal processing

To allow additional processing in today's narrow band telecommunication networks (300 Hz – 3400 Hz) the speech signal coming from the network going to the ear of HI user has to be of highest quality. This highest quality possible would be achieved by linear PCM coding (logarithmic PCM coding within telephone networks), which requires

- No source coding (speech codecs)
- No psychoacoustic-motivated coding (MPEG2, MPEG4, ATRAC, etc.)
- No transcoding (which is an outcome of denying other codecs than linear (logarithmic) PCM)

To ensure the transmission quality, Next-Generation-Networks (NGN) allow Quality-of-Services (QoS) tracking, which means that NGNs allow different quality for different prices. Here, higher quality pays off, in case the HI subscriber would like to use network-based assistive technology. In case G.711 (ITU-T Rec. G.711, 1993) coding is ensured for the entire transmission, the PCM coding would allow distributed services within the network. In case the network transmission is based on codecs other than the G.711, one compromise can be to allow high quality coding like the AMR12 codec (ETSI Rec. GSM 06.90, 1998) throughout the entire network until the gateway. In the gateway AMR12 to G.711 transcoding prepares the speech signal for network-based processing. Finally, the enhanced speech signal requires logarithmic PCM (G.711) transmission between the gateway and the HI subscriber's terminal equipment.

However, these additional processing solutions may come to some limits within the telephone network or terminal equipment e.g. in the long term the terminal equipment phone's signal amplifier circuits have to be capable of handling the increased gain. So far changes in the network topology and changes in the gain structures have to be accepted as standards.

5. Conclusions

We discussed the basic requirements of speech telephone signals for high frequency HI subscribers with a hearing loss up to 50 dB and type of ski slope. The presented solutions can be split to two major groups. One group allows the highest quality available, but the solutions remain stationary as they are terminal equipment-based and they require an audiologist for achieving optimum results. Moreover, these audiologists should be aware of certain telephone problems like telephone speech signal levelling or telephone frequency characteristics, to name just two of them. The second group covers network-based solutions which still allow speech signal improvement, at nearly no costs and with flexible routing. The author estimates the later solution to be of more success, as the ease of accessibility will be the main point for the final decision. For network vendors this means that whoever is first on the market with improved services may keep his hearing impaired subscribers and win new HI customers because of improved speech signals, resulting in enhanced speech signal quality. As shown in the beginning, HI subscribers will become a substantial part of the telecommunication subscribers in the future.

Acknowledgement

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