REAL-TIME FEEDBACK CANCELLATION IN HEARING AIDS

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1. INTRODUCTION

Feedback is a particularly debilitating problem in hearing aids. Feedback happens when the closed-loop system gain reaches values larger than unity and the phase of the feedback signal is 0^o or an integer multiple of 360^o (the Nyquist criterion). In digital systems and devices, solutions to the problem are implemented in the form of feedback reduction algorithms. [1,2,3]

The computational power in many hearing aids has been limited but cancellation methods are slowly becoming more effective. Adaptive anti-phase feedback canceling appears to be an optimal solution, although it requires significant dsp resources. The system continuously detects changes in the feedback path and, once feedback is detected, an anti-phase feedback signal is generated to cancel it. [4,5,6]

2. OVERVIEW

The fundamental issue with feedback management is the reliable and rapid detection of the onset of feedback. What is really desired is an effective method, which can detect feedback reliably and quickly with a minimum computational cost. Then a solution is required to adaptively cancel the feedback quickly while, at the same time, maintaining the input signal quality unaffected even for multiple feedback paths. By doing so, the wearer of the aids is not subjected to any annoying or upsetting feedback signals during a telephone call, or during meals and other daily activities requiring jaw movements.

In order to prevent any audible feedback reaching the hearing aid user's ear we need to detect the onset of the feedback build-up pattern and then to destroy the build-up very quickly. Most current feedback detection technologies, for example an anti-phase feedback canceller, need about 200 ms to detect a feedback path. Then it might need another 200 ms to eliminate feedback in the anti-phase feedback canceler. Therefore, a short burst of feedback is usually audible before it is canceled. This is perceived as annoying and can, at times, be uncomfortable.

Modern digital hearing aid amplifiers usually have multi-band filterbanks and feedback can occur in one or several of these bands. A new design of our digital hearing aids contains independent feedback detectors in each frequency band. These feedback detectors continuously monitor and detect feedback in real time independently and simultaneously in all individual frequency bands.

The signal strength in each band varies with time. In addition, the input signal changes its frequency components over time. An independent feedback detector analyzes the signal in each frequency band. Once feedback is detected in a frequency band, processing is applied to cancel the feedback instantaneously.

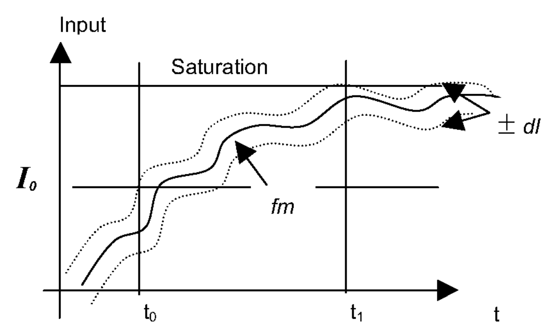
Our technique detects feedback during its build-up phase and destroys the feedback during the early build-up phase. In this way, the feedback burst duration is usually too short, or the feedback burst intensity too low, to be noticed. The method also uses multi-detectors and multi-cancellers operating independently in each frequency region in order to handle multiple feedback paths efficiently.

3. FEEDBACK DETECTION

Detection of feedback onset is a critical element of the method. Five criteria have been integrated together to rapidly detect feedback during its build-up phase. The methodology on which this detector is based is referred to as "tunnel within the frame".

The criteria that are integrated into the feedback detection module are listed here:

- Continuous and limited input signal level variation ($\pm dI$)
- Continuous modulation of input signal level (*fm*)
- Duration of a specific input signal ($dt=[t_1-t_0]$)
- The level of input signal (I_0)
- The difference between the current gain to the maximum deliverable gain.



Figdure 1: Feedback detection in a band

As shown in Figure 1, the input signal in a narrow frequency band has entered the narrow tunnel with a ***dI*** variation and a slow modulation frequency ***fm.*** If the signal persists over a certain duration ***dt*** and finally crosses over the minimum threshold I_0, it is detected as a potential feedback signal in this frequency region. The typical feedback build-up time in a BTE hearing aid is about 200 ms. Feedback modulation can be affected by the compression characteristics and the actual acoustic feedback path. The final criterion integrated into our feedback detection is a comparison of the actual gain with the maximum gain (which is the maximum gain for the hearing aid set at time of fitting). Feedback is beginning to build up when the system gain is close to this maximum gain. Feedback starts when the Nyquist criterion is met. A telephone or a hand close to the hearing aid, or touching it, will cause a departure from the stable closed loop system gain that has been established at time of fitting.

4. FEEDBACK CANCELLATION

One example of such an adaptive feedback canceller is a feedback canceller with fixed feedback margin. When feedback is detected, the adaptive feedback canceler modifies the system gain around the knee-point T_1 by the fixed feedback margin shown in Fig. 2. This is done over a very narrow input signal range so that the overall dynamic input signal, such as speech and music, will not be significantly affected.

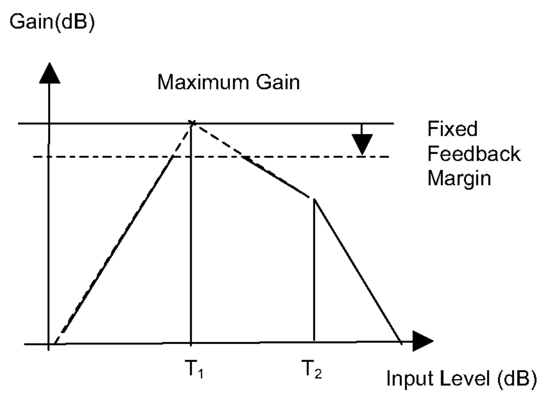


Fig. 2: Adaptive feedback canceller in a band

The output signal in the particular frequency band with a potential for feedback will be affected depending on how close the signal input is to the knee-point T_1. The maximum gain reduction occurs when the input signal coincides with the knee-point T_1. Experiments show that a 12 dB feedback margin provides the best performance in cancelling feedback without affecting signal quality. The farther the input signal level deviates from the knee-point T_1, the less will the gain be affected. The gain reduction is adaptively applied and adaptively removed in accordance with the continuous feedback detection decision.

The simplicity of using a fixed feedback margin is also its principal drawback, because it is not necessarily optimized to provide the best performance for all different hearing aids and different degrees of feedback. Sometimes, it might reduce gain more than required. At other times, the feedback canceler might under-react and not cancel the feedback completely. These considerations lead to the development of a Double Adaptive Feedback Canceller. Once feedback is detected during the build-up phase, or even when feedback is already established, this canceller will first apply a small feedback margin, such as 3dB. If the feedback is canceled immediately, it will stay with the small feedback margin. If the feedback still exists or continues to build up, the feedback margin is adaptively increased until the feedback is completely eliminated.

5. RESULTS

Two separate studies evaluated the real-time adaptive feedback canceller in a digital hearing aid during telephone use. The Unitron (UHL) study was a field trial with 24 hearing impaired subjects. A sepaerate study was carried out at the University of Buffalo (UB), with 25 patients. Hearing losses ranged from mild to severe and hearing aids included CIC ITC ITE and BTE styles. The results are shown in Figure 3.

	UHL	UB	
	% users	% users	% calls
Success	72	64	78
Problems	28	36	22

Figure 3. Field trial results

6. SUMMARY

A very fast and efficient multi-band feedback detection and cancellation method has been developed. Detection and cancellation of potential feedback takes place in in less than 100 ms, sometimes even before feedback is fully built up and becomes noticeble.

7. REFERENCES

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