

THE BENEFIT OF EFFECTIVE FEEDBACK CANCELLATION

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Acoustic feedback has been a hassle for as long as there have been hearing aids. Improvements have come gradually and finally brought about a level of satisfaction. Feedback canceller performance is one of the main topics of this white paper. Other topics are the relevance of feedback cancellation in today's hearing instruments, the nature of acoustic feedback, the implications of inadequate solutions, and the evolution of feedback cancellation over time.

Feedback Cancellation – the Key to the Success of Open-fit Hearing Aids

Over the last decade, BTE hearing aids have achieved enormous success. Compared to other hearing aid styles, their use increased throughout the world. In the United States, for example, it more than tripled – from 20% of all fittings in the year 2000 to 70% in 2011 (Kirkwood, 2012).

The revival of the BTEs is based on good reason. Today's BTE instruments represent a new hearing aid style that emerged only after the turn of the millennium: the mini-BTEs with thin tubing and dome, or with the receiver in the ear. In contrast to traditional styles, they leave the ear canal wide open. As a result, sound leaks out of the canal – a situation that was sure to produce a feedback howl in the old days. Nowadays, however, acoustic feedback is much less of a problem due to electronic countermeasures. As a matter of fact, the success of open fittings is closely related to the progress in digital signal processing, particularly to adaptive feedback cancellation.

Acoustic Feedback – the Root Cause for Loss of Confidence

It is annoying when a hearing instrument starts to whistle. At the moment when whistling sets in, an instrument is no longer of use. Such an incident causes loss of confidence and may result in clients rejecting the use of hearing aids.

As mentioned before, acoustic feedback happens when amplified sound leaks out of the ear canal. In fact, a feedback howl occurs when an instrument amplifies more than the feedback path from the receiver back to the microphone attenuates. In that case, the feedback sound reaches the microphone at a higher level than when it reached the microphone the first time. Hence the sound gets louder and louder as it goes through the hearing aid again and again, until it finally reaches maximum power output. This all happens very fast, indeed within milliseconds.

When a hearing instrument whistles, it is of no use. But there are feedback problems even before whistling occurs, namely, when the hearing aid gain is only slightly below the value at which the hearing aid starts whistling. In that case, the instrument already produces an unnatural sound that may entail a reduction in speech understanding. This effect, known as sub-oscillatory feedback, calls for a safety margin: as a rule of thumb, hearing aid gain should be 6 dB below the value at which feedback whistling sets in.

There are more reasons for a safety margin. It is clearly not sufficient when a hearing instrument operates without feedback under ideal conditions only. Feedback-free operation is also needed under real-world conditions, including tonal sound sources and nearby obstacles that reflect the sound.

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Even today, the countermeasures against acoustic feedback comprise two inadequate solutions: setting the gain below prescribed targets and occluding the ear canal. Both solutions produce undesirable side effects. Gain below target reduces audibility and possibly speech understanding. Occluding the ear canal, on the other hand, causes a sense of pressure, a hollow sound of your client's own voice, and an overly loud sound while chewing. This loud sound is particularly annoying because it makes it difficult to participate in discussions while eating. At the table, we are used to alternately either talking or listening while chewing. But with occluded ears, your clients will have problems understanding their discussion partners.

Progress thanks to Digital Signal Processing

With the transition from analog to digital technology came progress. The reason is that adaptive signal processing algorithms became available. Some of these algorithms lend themselves to acoustic feedback cancellation.

The adaptive feedback cancellation algorithms take so much computation power, however, that early hearing aid implementations allowed no more than a basic configuration. It is only later that refinements became possible, refinements that address acoustic feedback under critical conditions such as in the presence of tonal sound sources and feedback path changes.

Current Status of Feedback Cancellation – Similarities and Differences

Ideally, a feedback canceller not only suppresses acoustic feedback but also makes a hearing aid comply with a number of additional requirements:

- allow fit-to-target;
- allow sufficient venting;
- withstand tonal sound sources;
- withstand changes to the feedback path.

Such a feedback canceller provides an enormous benefit to all hearing aid styles: feedback-free operation in real-world situations. In some cases, it is even possible to increase gain without jeopardizing the feedback-free operation, or to use a more open fit. All these advantages result in higher customer satisfaction.

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The possibility of a more open fit without jeopardizing the feedback-free operation actually explains the success of the open-fit mini-BTEs. In a recent market survey, Kochkin (2010) indeed reports that with respect to chewing/swallowing sound, mini-BTE hearing aids are rated 13% higher than traditional style hearing aids – and 11% higher with respect to the sound of one’s own voice. The conclusion is that effective feedback cancellation helps to alleviate undesired side effects of the traditional styles.

Market surveys, however, show an overall picture only. Some readers may assume that feedback cancellers of different brands show more or less the same performance. This impression may arise as well from the fact that feedback cancellers of different brands share similar adaptive processing algorithms. But in reality, the performance of feedback cancellers differs from one brand to another. Such differences become evident from technical evaluation studies, e.g., Freed and Soli, 2006; Merks et al., 2006; Parsa, 2006; Shin et al., 2007; Ricketts et al., 2008; Spriet et al., 2009.

Unfortunately, there is no standard method for evaluating the performance of feedback cancellers. Hence comparisons between studies are difficult. Often, hearing aids are tested on an acoustic manikin only. In this way, average performance is measured, but the variability across subjects is overlooked. The variability across subjects is, of course, due to differences in the size and shape of ear canals, as well as of receiver placement. But as it will turn out, the variability also depends on the instrument under test. On the same set of subjects, different instruments show more or less variability. So, in addition to the average performance, it is also of interest to look at the variability.

A comprehensive study that looked at both average performance and variability is the one by Ricketts et al. (2008). The researchers investigated six commercially available hearing instruments of different manufacturers. They fitted them on sixteen subjects plus an acoustic manikin. Then, they determined additional gain before feedback (AGBF), using probe microphone techniques. In their report, they detail the AGBF measurement, concluding that “AGBF is expected to be nearly identical in magnitude to added stable gain”, the more widely used measure.

Ricketts et al. (2008) report a range of AGBF across instruments from 0 to 15 dB, consistent with other recent studies. And with respect to the variability across subjects, they note that “the range of AGBF values was as small as 7 dB and as large as 16 dB depending on the specific feedback suppression algorithm, suggesting that some models are much more robust than others.”

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As the results of the study show, the difference between brands is enormous. It reflects the challenges encountered in feedback cancellation.

Over the years, engineers have experimented with various techniques, the details of which exceed the scope of this paper. Nevertheless, it may provide a sense of the difficulties involved when simply looking at the proposed techniques:

- initializing the adaptive algorithms with start-up values to speed up performance after resets;
- using subliminal probe signals to improve the estimate of the feedback path;
- conditioning the control signals of the adaptive algorithms to speed up the adaptation to feedback path changes;
- varying the adaptation speed of the adaptive algorithms in accordance with the type of signal present;
- shifting the frequency of the output signal to break the feedback loop;
- modulating the amplitude and/or phase of the output signal to distinguish it from free field signals;
- reducing the gain temporarily in specific frequency intervals to overcome critical conditions.

The list is not intended to be exhaustive. But it may still indicate possible reasons for the reported differences.

Best Scores for Adaptive Feedback Canceller Plus

The Adaptive Feedback Canceller Plus (AFC Plus) is Bernafon's latest achievement in feedback cancellation. Its kernel comprises an adaptive algorithm that allows effective feedback cancellation. In addition, there is circuitry to cope with the particular difficulties of tonal sound sources and feedback path changes. The additional circuitry has been elaborated to a level of sophistication that maximizes performance while avoiding audible artifacts. Internal tests showed favorable results, as reported separately in an article of the Bernafon Topics in Amplification series. The focus of these tests was to see whether hearing aids of different brands withstand changes in the feedback path. To that end, a rotating cup was used to simulate the movement of a hand or telephone handset over the hearing aid. Out of five competitors' hearing aids, only one succeeded in avoiding a feedback howl, as did the AFC Plus. But how would that result compare to the results of other evaluation studies?

As mentioned before, comparisons between tests are difficult because of differences in test methods. The only way to make a fair comparison was to give the task to an independent institution. Prof. Ricketts and his team at Vanderbilt University have developed expertise in this field and continue to test feedback cancellers. The AFC Plus was submitted and included in their test set.

In a first round, the researchers at Vanderbilt determined additional gain before feedback (AGBF). They found the AFC Plus equal in performance to the average of the six other brands at 2 kHz, but better at 3 kHz and 4 kHz. In the meantime, however, they refined their test methods. In their new test, they determine maximum real ear insertion gain before feedback. This new criterion has a clear advantage, as it quantifies the benefit for your clients in an unambiguous way. In contrast, the AGBF value indicates a relative improvement only.

In the new test, the researchers did open fittings on twenty patients, again using probe microphones to assess real ear aided response. And again, they tested under real-world conditions, including tonal sounds and nearby obstacles. Subjects were asked to elicit feedback intentionally, using head and jaw movements, whistles, and bringing a hand close to the hearing aid. Moreover, the operation of an instrument was only judged feedback-free when it maintained a high quality of sound under these conditions. The results shown in Fig. 1 should therefore be considered as a conservative estimate.

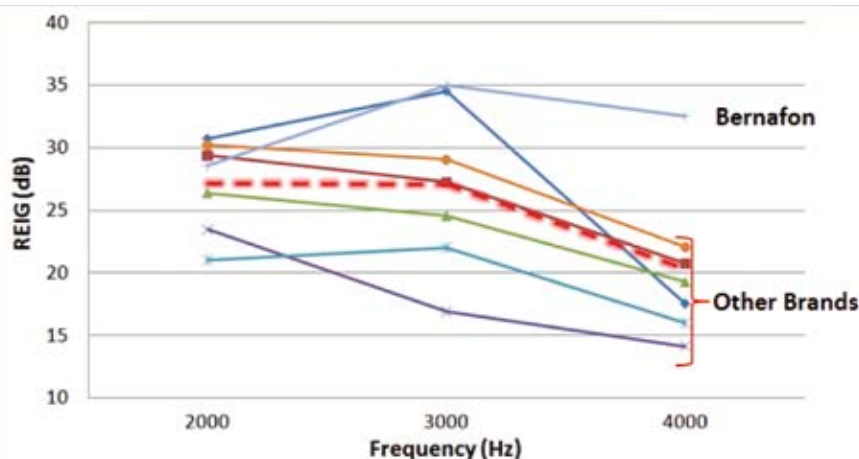


Figure 1: Maximum real ear insertion gain before feedback

Whereas the performance of all other brands drops to below 25 dB at 4 kHz, the AFC Plus exceeds 30 dB at both 3 and 4 kHz.

Fig. 1 shows seven solid lines of different color, each representing the performance of a particular hearing aid brand. In addition, there is a dashed red line that shows the average performance of all brands. First of all, the diagram shows a clear distinction between brands. Whereas the performance of all other brands drops to below 25 dB at 4 kHz, the AFC Plus exceeds 30 dB at both 3 and 4 kHz – with an advantage of 10 to 15 dB compared to the competitors' average.

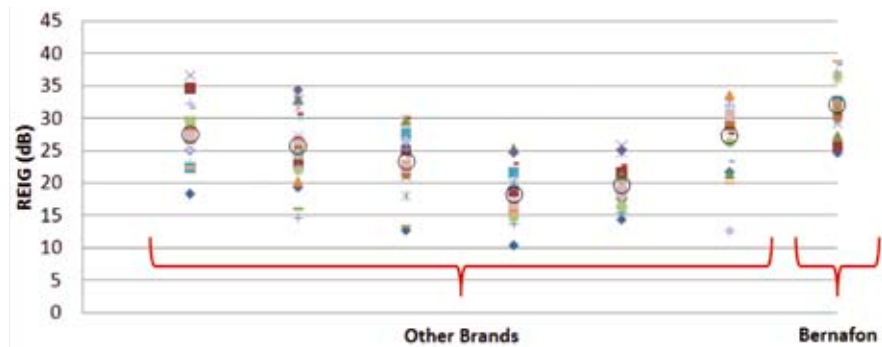


Figure 2: Individual maximum real ear insertion gain across subjects

The advantage of the AFC Plus extends to the variability across subjects. Each symbol in Fig. 2 shows a client's maximum real ear insertion gain, averaged across the three measurement frequencies of 2, 3, and 4 kHz. Whereas all other brands have minimum scores in the range of 10 to 20 dB, the AFC Plus performs at a minimum of 25 dB. Furthermore, the AFC Plus also reaches the highest individual maximum at close to 40 dB.

The test results
prove the
excellence of the
AFC Plus.

Implications for Practice

Effective feedback cancellation is the only sensible way to deal with the problem of acoustic feedback. In fact, the better a feedback canceller performs, the larger the fitting range of a hearing instrument and the greater the benefit to all clients.

The data collected at Vanderbilt University have been part of recent presentations (Ricketts, 2012), and a manuscript is in the works. The test results prove the excellence of the AFC Plus. Look for Bernaфон's hearing aid family Chronos and use its excellent performance to your advantage – and to the advantage of your clients.

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