Acoustic Optimization of Gain, Feedback, and Occlusion in CIC instruments

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Background

- The increase in popularity of “mini” and “micro” behind-the-ear (BTE) devices has been due, in part, to the effective combination of style and substance that appeals to a new generation of hearing aid users.
- A survey (Kochkin 2006) indicates that slim tube, “open” fit devices have increased first-time wearers by 29%, lowering the average age by nearly a decade.
- Yet completely-in-the-canal (CIC) devices have remained relatively stable at 10% of the total. This statistic suggests that some consumers still prefer the cosmetic advantages and ease-of-use of this style of hearing aid.
- Although directional microphones are not practical for use with CICs, preservation of pinna and concha resonances provides directional benefits comparable to those with the unaided ear (Roberts and Schulein, 1997).
- CICs have enjoyed limited success with high-frequency losses due to feedback, occlusion, and gain limitations.
- Recent technical innovations address some of these shortcomings. This poster reports the technical and performance evaluation of a new CIC open fit system.
- Results indicate excellent feedback prevention and sound quality, in combination with reduced occlusion when compared to other commercially-available devices.

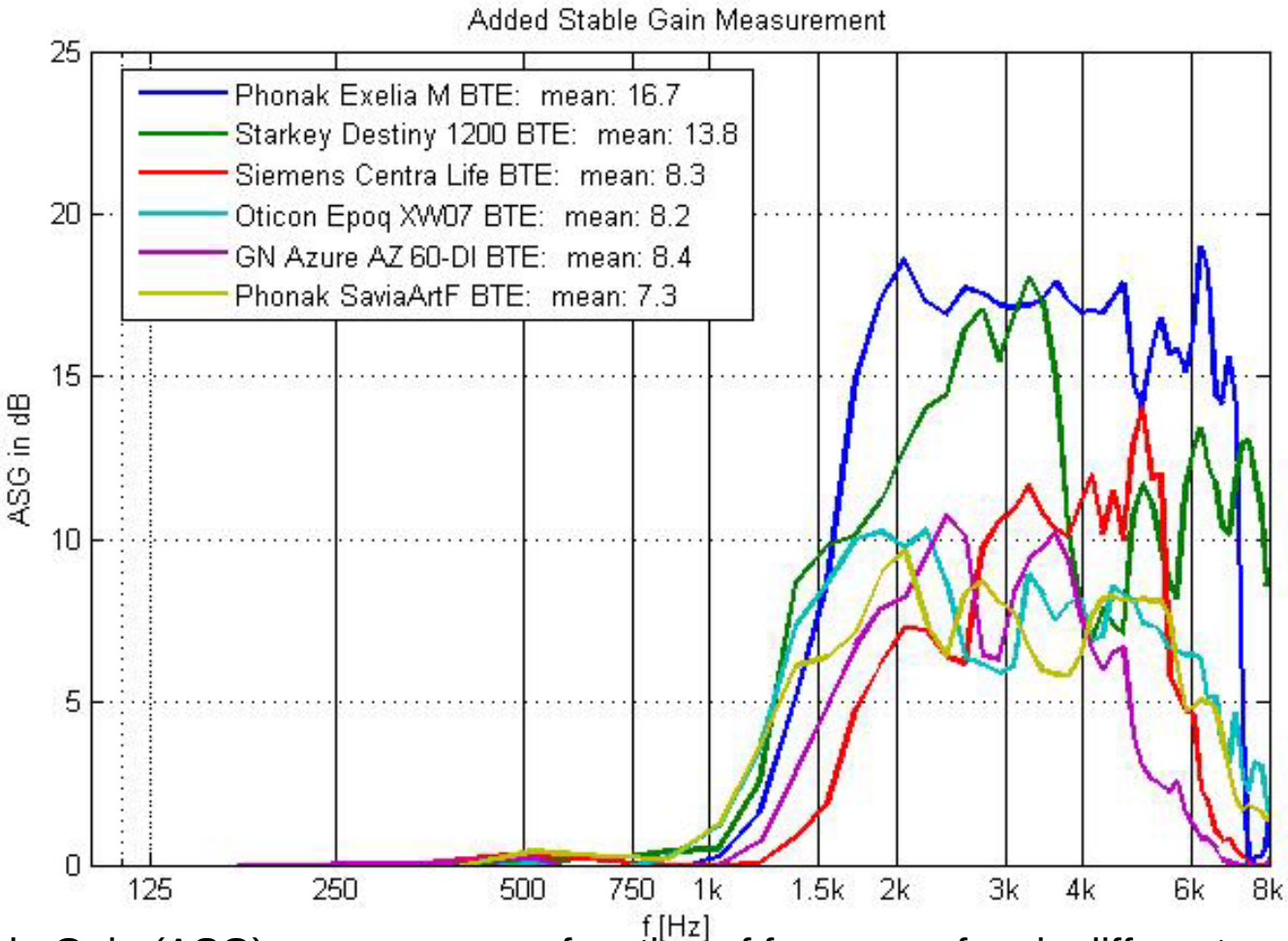
Objectives

- Will acoustic optimization of venting and hearing aid parameters provide smoother *in-situ* responses that relate positively to user benefits, in terms of sound quality, occlusion, and speech intelligibility? That is, rather than simply designing the vents to be as large as possible, given the size of the components, does it make sense to design and optimize the locations of vent pathways and internal hearing aid components to best match the acoustic properties of the device to the patient's ear?

- Can feedback and occlusion be reduced in CIC instruments to comparable levels for micro BTE devices for typical open fit candidates?

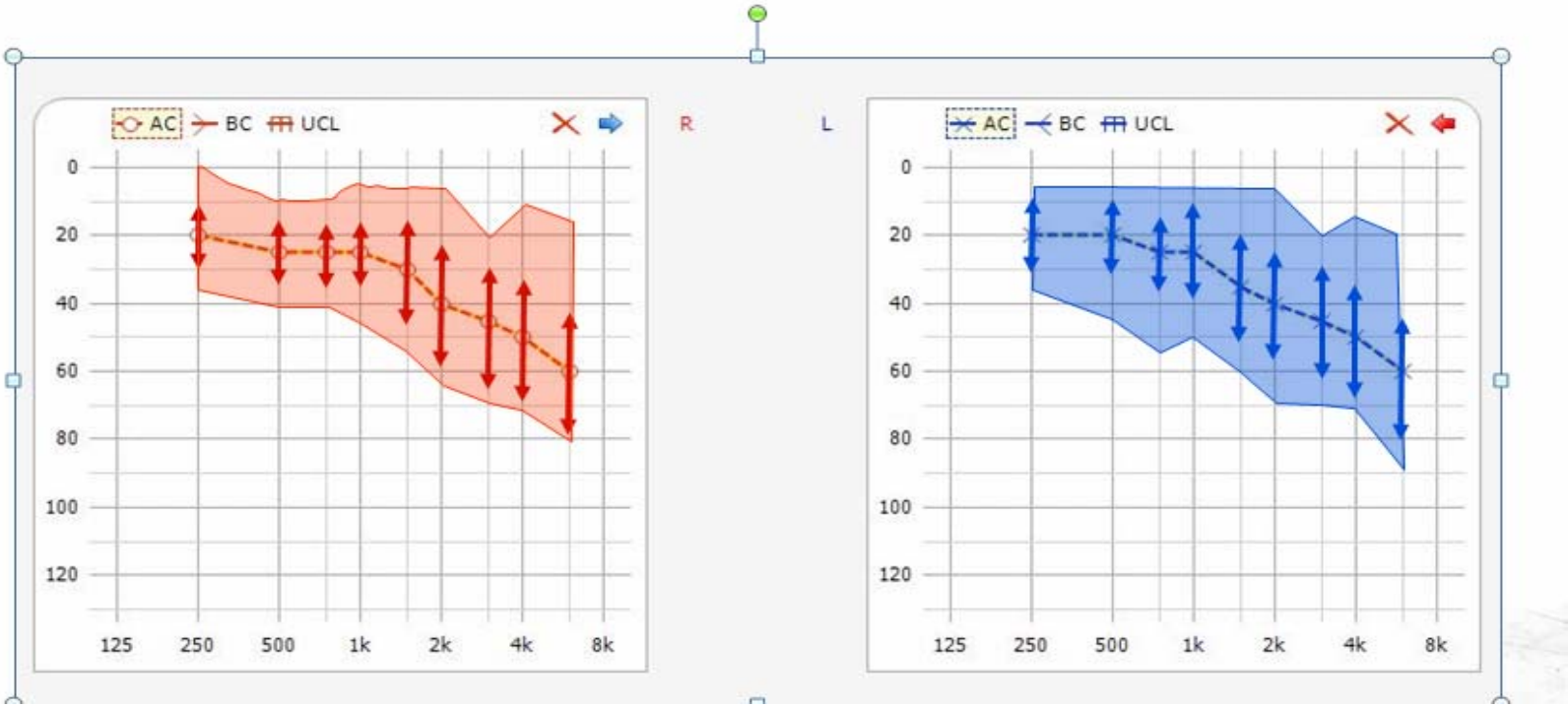
- Will state-of-the-art feedback management provide effective performance in combination with speech audibility for varying speech input levels?

Laboratory Assessment of a new feedback cancellation algorithm



Added Stable Gain (ASG) measures as a function of frequency for six different commercially available open fit hearing aid systems using the procedures developed by Freed and Soli (2006) and Merks et al (2006).

Clinical Assessment of a new CIC open fit device



Twenty-six (16 male, 10 female) hard-of-hearing patients served as subjects. Average age was 65 years, and the majority were previous hearing aid users. Audiometric characteristics (average, standard deviation, and range) for right (red) and left (blue) ears of the 26 subjects who participated in the study.

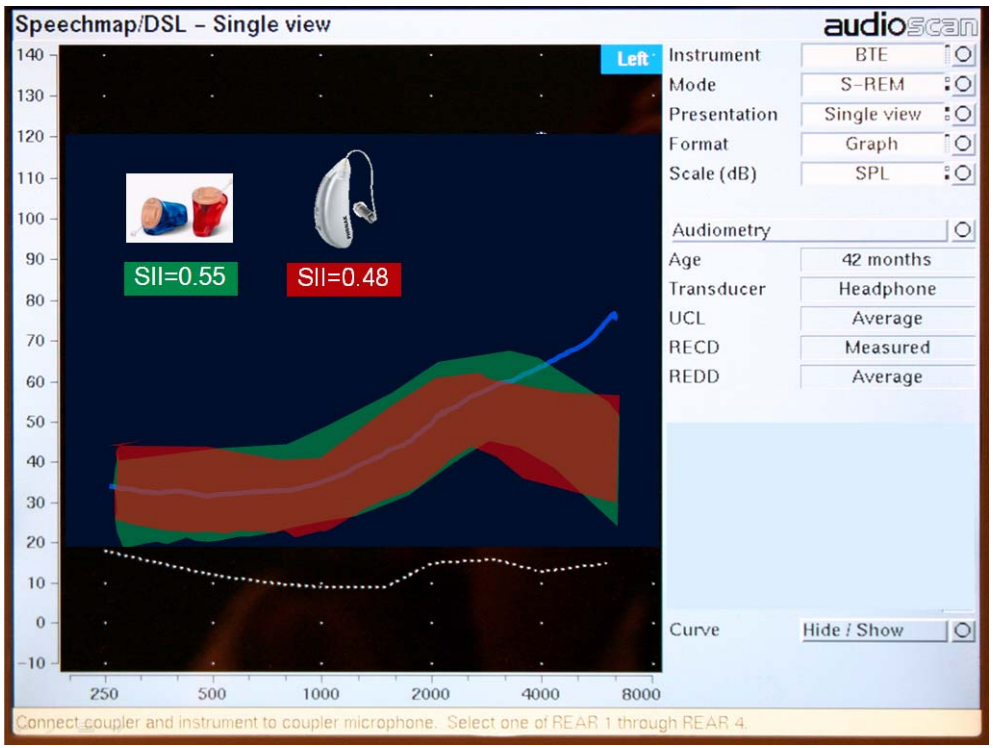
Procedure

- Each subject was fitted binaurally with three sets of hearing aids
  - Exelia CIC with Acoustically Optimized Venting (AOV)
  - Savia Art CIC with IROS venting
  - Savia Art CRT BTE with Open Dome Tip
- The hearing aids were programmed, using each subject's audiometric thresholds input into iPFG V2.0 software, to meet NAL-NL1 prescriptive targets.
- Real-ear measurements were made, using the Audioscan Verifit, to evaluate speech audibility for soft (50 dB SPL) and moderate (65 dB SPL) recorded speech for a male talker (carrot passage), and that loud sounds (85 dB SPL MPO sweep) did not produce loudness discomfort.
- Speech Intelligibility Index (SII) measurements were computed for each instrument for the 50 and 65 dB SPL conditions, to evaluate the degree to which each system provided speech audibility for real-world stimuli. The SII has proven to be a very robust predictive measure for predicting performance for both normal-hearing and hearing-impaired persons in a variety of listening environments.

Procedure

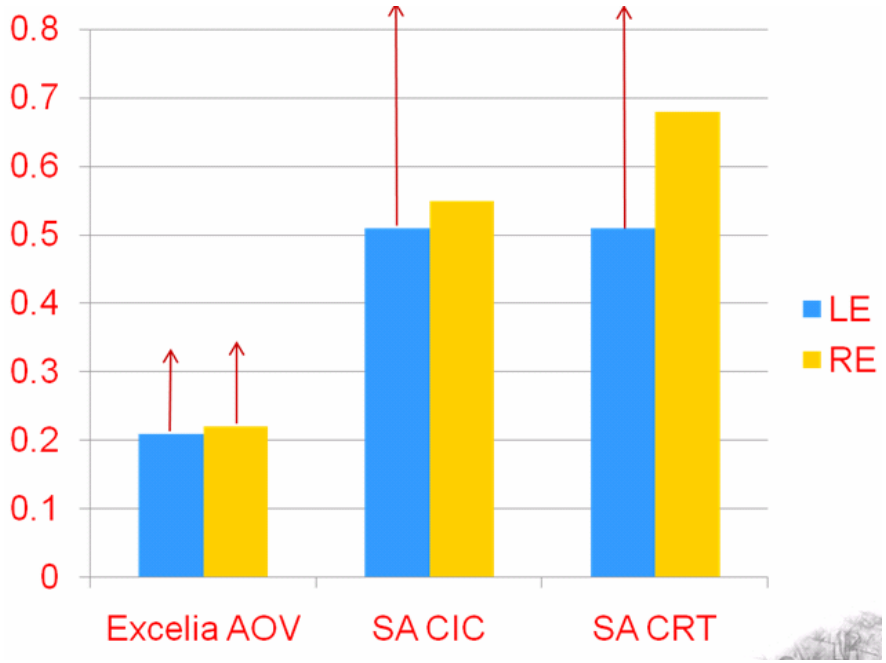
- Subjects evaluated the effectiveness of the feedback cancellation system for each device under three conditions:
  - When the feedback test was not completed
  - When the feedback test was run with the instrument in the 2-cc coupler
  - When the feedback test was run *in-situ* using the iPFG fitting software
- For each condition, both ears were tested for the presence of feedback under “dynamic” listening conditions, by slowly moving the subject’s left or right hand in a parallel plane from the pinna, beginning at 12 inches and moving until feedback occurred. The hand-to-ear distance (in inches) when feedback occurred was recorded binaurally for all three hearing aids.
- For each condition, subjects rated the sound quality of two music passages for sound quality and the presence of entrainment.
- Each subject wore the Exelia CIC AOV devices for a period of two weeks, after which they completed a subjective questionnaire regarding the benefits in terms of sound quality, speech intelligibility, occlusion, and feedback.

Results - Audibility



- Soft input average calculated SII was greater for Exelia AOV (0.55) than for Savia Art CRT (0.48)
- Improved feedback canceller provided increased audibility for soft sounds
- Results of subjective occlusion ratings were comparable or better to Savia Art CRT
- This combination of improved audibility for soft speech and comparable subjective occlusion values suggests that acoustically optimized venting, in combination with effective feedback cancellation, provides a favorable outcome for the CIC device with open fittings.

Results: Feedback



- For all three hearing aids, optimization of the feedback cancellation system via *in-situ* feedback measurement resulted in NO feedback for static listening conditions.
- "Dynamic" feedback test revealed a statistically significant improvement for Exelia AOV versus the Savia Art CIC and CRT devices. For left and right ears, respectively, feedback occurred with the subject's hand moving toward his/her ear at a distance of 0.21 and 0.22 inches with Exelia, while both Savia Art models produced feedback at an average distance in excess of 0.5 inches.

Results: Sound Quality

- Smoothness of Real-ear Aided response (REAR). Using a modification Frequency Response Smoothness Quantification Index (FReSQI) developed by Schultz et al (1992), which determines the irregularity of hearing aid frequency responses by computing the "error" between the REAR and a second order polynomial computed between the selected low- and high-frequency cutoff. Using this measure, the computed FReSQI values were lower for Exelia CIC AOV (15.1) than for either the SAVIA Art CIC (26.1) or Savia Art CRT (25.2).

- Subjective Questionnaire. Subjective questionnaire data were obtained from the subjects after a two-week trial period with the Exelia CIC AOV. Results indicate that subjects wore the hearing aids an average of 9.5 hours daily, for a total of 155 hours total use, excellent subjective performance for loudness, speech intelligibility in quiet and in noise, for the loudness and sound quality of their own voice, and for overall satisfaction.

Summary

- Acoustic optimization of venting and hearing aid parameters provide smoother *in-situ* responses that relate positively to user benefits, in terms of sound quality, occlusion, and speech intelligibility.
- Measured feedback and occlusion with the Exelia CIC was reduced relative to those observed with the Savia Art CRT micro BTE device for typical “open fit” hearing aid candidates.
- Exelia’s improved feedback management system resulted in improved feedback cancellation for “dynamic” listening conditions while also providing improved audibility for soft input speech levels.
- Effective performance with “open” fit devices depends on:
  - Smooth *in-situ* frequency response
  - Occlusion management
  - Audibility for soft speech and other sounds
  - Prevention of feedback for static and dynamic listening conditions

Achieving these objectives will provide a successful prescription with these devices, providing patients with another alternative for open fit in addition to micro BTE devices.