Clinical evidence for the accuracy of REM and in-situ audiometry with AMO 2.0

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Key takeaways:

- Acoustic Model Optimization (AMO) 2.0, a feature introduced in Omega AI, leverages electroacoustic in-situ measurements during Feedback-Canceller initialization to individualize the acoustic model inside Starkey's fitting software (Pro Fit).
- The acoustic model serves to predict real-ear responses and gains, which are used to automatically pre-set hearing aid gains with 'Best Fit' or 'Target Match', and to set tone levels in the In-Situ Audiometer.
- Clinical findings show significant improvements in accuracy over the previous version of AMO for both in-situ audiometry and Target Match performance.

Introduction

Accounting for acoustic differences between individuals when fitting hearing aids is essential to ensure optimal performance and user satisfaction. The unique characteristics of an individual's ear canal and of its physical coupling with the hearing aid shell, mold, or dome can significantly influence sound pressure at the eardrum (real-ear response) and ultimately, the user's perceptual experience. If individual acoustic differences are not considered during the fitting process, the resulting real-ear gains, speech audibility, and loudness percepts may depart from those targeted by the fitting formula selected by the hearing care professional. Thus, addressing individual acoustic effects early in the fitting process can reduce the need for extensive follow-up adjustments.

Traditionally, first-fit algorithms have relied on non-individualized acoustic models based on average real-ear measures (REM) across many individuals.

Because such 'average' acoustic models do not represent the diversity of individual real-ear responses, their predictions can deviate substantially from the real-ear responses measured in an individual.

Advanced fitting tools like Starkey's Acoustic Model Optimization (AMO) help bridge this gap by incorporating individual acoustic characteristics into first-fit computations. A primary aim of AMO is to enhance first-fit accuracy, to make the fitting process more efficient and ultimately, more satisfactory.

While the original version of AMO introduced into Pro Fit with the Genesis AI product family marked an important step towards the 'automatic' personalization of Starkey's first fit ('Best Fit'), this first version (herein referred to as AMO 1.0) focuses on one aspect of real-ear acoustics individualization: vent-effect estimation.

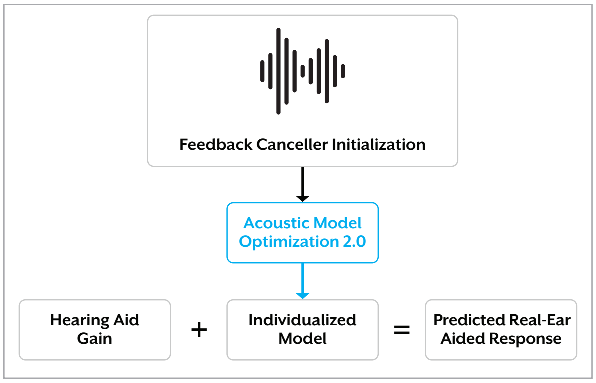

Figure 1: Schematic Acoustic Model Optimization 2.0. process. The AMO 2.0 algorithm uses in-situ electroacoustic measures obtained as part of the Feedback-Canceller (FBC) initialization, to yield an 'individualized' acoustic model. The acoustic model is used in Starkey's fitting software (Pro Fit) to compute Predicted Real-Ear Aided Responses and Best-Fit gains. It can also influence other fitting features, such as in-situ audiometry.

AMO 2.0 advances this approach by using a more advanced, generative algorithm to yield a more complete and precise model of individual real-ear acoustic effects *(see Figure 1)*.

Results of a recent lab study *(Micheyl et al., 2025)* demonstrated improvements in Best-Fit accuracy with AMO 2.0 compared to without, i.e., using the default (non-individualized) acoustic model in Pro Fit. As expected, the largest improvements were obtained with fittings in which the real-ear acoustic coupling did not match the default (non-individualized) model predictions based on the acoustic option selected in Pro Fit. These results provide objective evidence that when such mismatches occur, AMO 2.0 can help greatly.

The present article provides further evidence for AMO 2.0 benefits in a clinical best-practice context, where the acoustic option selected in Pro Fit always matches the in-ear coupling. The report is intended primarily to help hearing care professionals understand when and how this optional feature may be advantageous, and what to expect when the feature is enabled in Pro Fit. In particular, in-situ audiometry and real-ear measures obtained in hearing-impaired participants are used to illustrate two clinically relevant tests of the Pro Fit acoustic model performance, influenced by AMO 2.0.

In-situ audiometry

Pro Fit's In-Situ Audiometer leverages the acoustic model to determine the in-situ test-tone SPL. Thus, its performance depends on how accurately the acoustic model predicts the real-ear SPL. AMO can influence this.

In a previous publication, AMO 1.0 was shown to yield significant improvements in in-situ audiometry accuracy, compared to the Pro Fit default (non-individualized) model *(Micheyl et al., 2023)*. The question addressed in the present study was whether AMO 2.0 can further improve in-situ Audiometer accuracy, compared to AMO 1.0.

To address this question, hearing thresholds were measured in-situ as well as with insert earphones (ER-3A) in 100 participants, of whom 53 were tested with Edge AI devices (including 23 with customs, of which 7 ITEs, 7 ITCs, and 9 CICs, and 26 with RICs, of which 12 with open domes, 11 with occluded domes, and 3 with earmolds), and 54 were tested with Omega AI devices (including 23 with customs, of which 6 ITEs, 6 ITCs, and 11 CICs, and 32 with RICs, of which 15 with open domes, 8 with occluded domes, and 9 with earmolds). Six participants were evaluated with both Edge AI and Omega AI devices. For both groups, FBC initialization with AMO 1.0 for Edge AI devices or AMO 2.0 for Omega AI devices, was run prior to in-situ audiometry.

In-situ Audiometer accuracy was evaluated based on absolute deviations between in-situ thresholds and thresholds measured at the same frequency and in the same ears, using standard insert earphones (audiological 'gold standard'). Assuming that insert thresholds are 'true' hearing thresholds, deviations between insert and in-situ thresholds likely reflect in-situ measurement errors. Those deviations that survive averaging across many participants likely reflect systematic errors of the acoustic model, aka, biases.

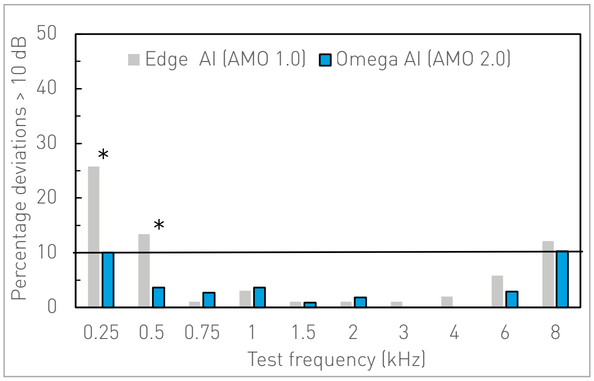

Figure 2: Percentages of in-situ/insert threshold deviations > 10 dB for each test frequency for the groups tested with AMO 1.0 (Edge AI) and AMO 2.0 (Omega AI). Stars: statistically significant differences (p < 0.05).

Figure 2 shows percentages of ears for which deviations between in-situ and insert thresholds exceeded 10 dB (twice the 5-dB measurement step-size) for the Edge AI (AMO 1.0) group and the Omega AI (AMO 2.0) group. Lower percentages indicate greater accuracy.

As can be seen, for the 250 and 500 Hz frequencies, the percentage of large (>10 dB) in-situ vs insert threshold deviations—across all participants tested within a group—with Omega AI (AMO 2.0) was significantly lower than for Edge AI (AMO 1.0), and no greater than 10% from 250 Hz to 8 kHz.

Figure 3 shows scatter plots of in-situ thresholds measured in the Omega AI group (with AMO 2.0) versus corresponding insert thresholds, for all test frequencies (a), and for the four-frequency pure-tone average (PTA4) (b).

In-situ and insert thresholds were highly correlated with each other at each frequency, with correlation coefficients generally higher than 0.9, except at 6 and 8 kHz *(Figure 4)*. For 0.5, 0.75, 1 kHz, and PTA4 the correlation coefficients were higher for AMO 2.0 (p<0.05).

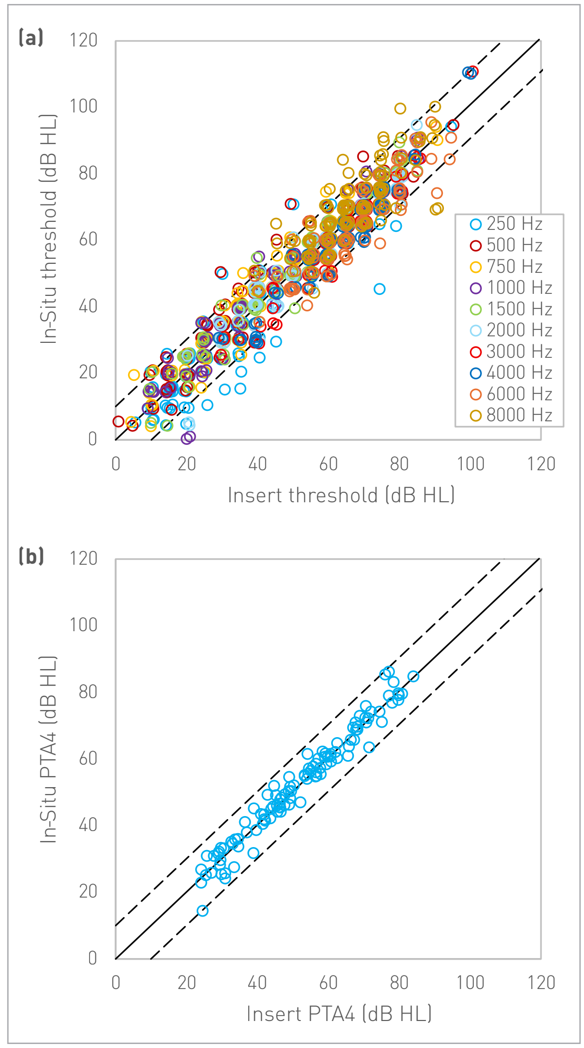

Figure 3: Scatter plots of in-situ versus insert pure-tone thresholds measured in the Omega AI with AMO 2.0 group. (a) Per-frequency thresholds. (b) Four-frequency (0.5, 1, 2, and 4 kHz) average thresholds (PTA4).

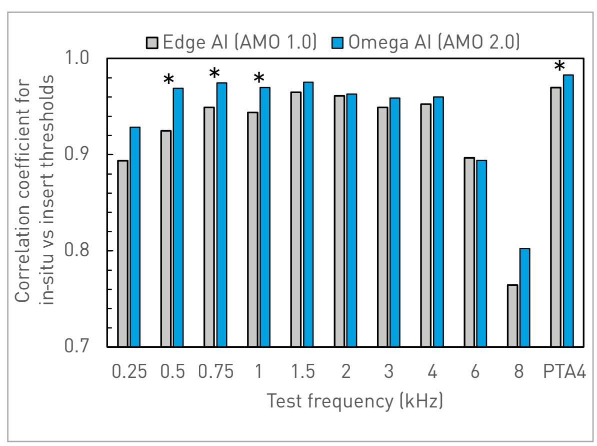

Figure 4: Correlation coefficients for in-situ versus insert thresholds for Edge AI with AMO 1.0 and Omega AI with AMO 2.0. Stars: statistically significant differences (p < 0.05).

Real-Ear Measures (REM)

To further assess the accuracy of the Pro Fit acoustic model with AMO 2.0, real-ear measurements (REM) collected using an Audioscan Verifit2 probe-tube system in 62 participants equipped with RIC or custom Omega AI hearing aids were analyzed. Differences between real-ear aided responses (REARs) measured following 'Best Fit' (after FBC initialization with AMO 2.0) and corresponding e-STAT 2.0 targets, were used to quantify first-fit errors for a 65-dB SPL speech input (ISTS, female), accounting for spectral specificities of the test signal.

Figure 5 shows median deviations of measured Best-Fit REARs from e-STAT 2.0 targets. For Omega AI with AMO 2.0, mean and median deviations were generally within 3 dB over this frequency range. For earlier (Genesis and Edge AI) products using AMO 1.0, somewhat larger median deviations (up to 5 dB) were observed at frequencies higher than 2.5 kHz.

Figure 6 shows the percentages of measured deviations between Best-Fit REARs and targets within 5 dB or less, per frequency. Higher percentages denote better accuracy. For Omega AI with AMO 2.0, the median percentage of deviations ⩽ 5 dB was above 66% (i.e., two thirds of fittings) up to 6.3 kHz.

How often does AMO 2.0 update the acoustic model?

As explained in the introduction, the AMO feature uses in-situ electroacoustic data to 'update' the acoustic model for the current fitting, thus going from a 'non-individualized' model to an 'individualized' model. Such model updates are not systematic but determined by the algorithm every time FBC-initialization is run.

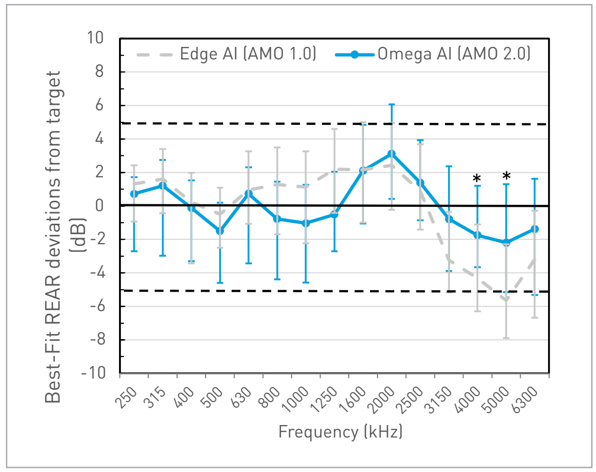

Figure 5: Median deviations of measured Best-Fit REARs from e-STAT 2.0 targets at third-octave frequencies (250 Hz -6.3 kHz), for Omega AI (AMO 2.0) and Edge AI (AMO 1.0). Error bars indicate first and third quartiles. Horizontal dashed lines indicate +/- 5 dB. Stars: statistically significant differences (p < 0.05).

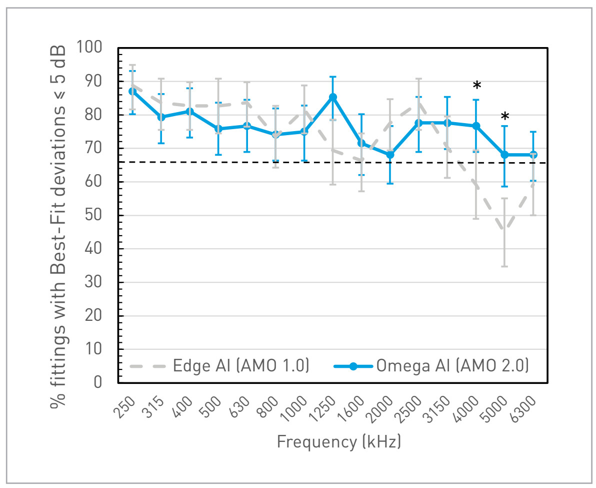

Figure 6: Percentages of Best-Fit fittings with REAR deviations from targets (e-STAT 2.0) ⩽ 5 dB at third-octave frequencies at third-octave frequencies (250 Hz -6.3 kHz), for Omega AI (AMO 2.0) and Edge AI (AMO 1.0). Error bars show 5th and 95th percentiles (bootstrap). Stars: statistically significant differences (p < 0.05).

Professionals who used AMO with Genesis or Edge AI products may notice that model updates are more frequent with AMO 2.0, especially for RICs. This is due to the algorithm ('logic') used to trigger updates in AMO 2.0 being more 'sensitive'.

Table 1: Summary of the percentage of vent recommendations received for the Omega AI RIC fittings, by coupling. 95% CI: two-tailed 95% confidence intervals for the population-mean percentage.

Acoustic coupling	Number of ears tested	Percentage of model updates received
Open Domes	32	91% (95% CI: 74 - 98%)
Occluded Domes	22	100% (95% CI: 84 - 100%)
Earmolds	22	82% (95% CI: 58 - 95%)

Table 1 shows the percentages of fittings with AMO 2.0 which received an acoustic-model update, across 38 participants (76 bilateral fittings) using an Omega AI RIC RT or mRIC R with an audiometrically appropriate acoustic coupling. For this sample, the measured percentages ranged from 82% to 100% depending on the RIC coupling used.

For comparison, an earlier study using Genesis AI RICs found only 10 of 32 fittings (roughly, 33%) receiving a vent-model update while using AMO *(Micheyl et al., 2023)*.

What happens after a model update?

While the decision to update the acoustic model is made automatically by the AMO algorithm, the decision to (re)apply Target Match or not following the acoustic model update is left to the hearing care professional. For a first fitting, the professional may decide to apply Target Match and thus let Pro Fit automatically readjust the applied hearing aid gains automatically. However, if FBC initialization is re-run at a follow-up visit after hearing aid gains have been manually adjusted, the professional may wish to skip Target Match—thus keeping hearing aid gains the way they are. In this case, only the Predicted Real-Ear Gains and Responses may be updated—unless AMO 2.0 is manually toggled off prior to re-running FBC initialization, in which case the real-ear predictions will also remain unchanged.

To help fitting professionals decide whether or not to update gains after an acoustic model update, the 'pop-up' on the Feedback Canceller (FBC) screen in Pro Fit has been updated to make it easier to see the change in Predicted Real-ear Responses resulting from an acoustic-model update *(Figure 7)*.

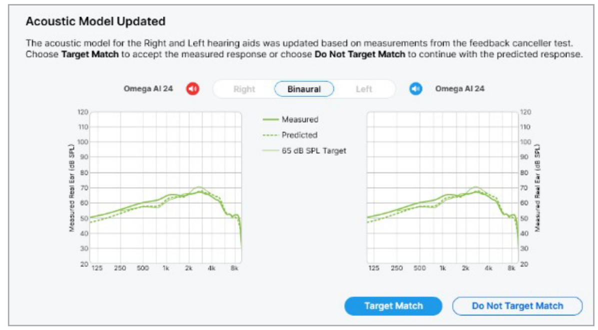

Figure 7: Example pop-up notification following FBC initialization when a vent recommendation has been received. The hearing care professional is asked whether they want hearing aid gains to be adjusted based on the recommendation to match targets.

Note that, for AMO 2.0 as for AMO 1.0, the default setting for the feature in Pro Fit is On, but the toggle on this screen can be switched to Off at will, which will disable the feature until it is toggled back On. When the feature is On, and the algorithm determines that an acoustic-model update is warranted, the update occurs automatically after FBC initialization without the need for user input. The assumption is that, if the professional has left the feature On, they want it to operate—if not, they can toggle it Off.

Conclusions

The present findings provide evidence for the accuracy and precision of automated first-fits ('Best-Fit') and in-situ audiometry in Pro Fit with AMO 2.0, in a clinical setting, using a combination of psychoacoustic and real-ear measurements.

These findings complement lab-test results obtained in another study, using a standard hearing research manikin *(Micheyl et al., 2025)*.

Nonetheless, verification of hearing aid fittings using probe-tube REM is still considered clinical best practice, and should be used to ensure accurate matching of prescriptive targets.

Because the AMO 2.0 algorithm relies crucially on in-situ electroacoustic measures performed during the Feedback-Canceller (FBC) initialization process, it is essential for fitting professionals to ensure that this process is performed in a quiet environment (such as an audiometric booth), with clean and properly functioning hearing aid receiver and microphones, and with the hearing aids properly inserted into the wearer's ear(s). For a binaural fitting with identical acoustic options for the left and right ears, it is recommended to run FBC initialization binaurally since, in this situation, AMO combines information from the left and right sides to yield inter-aurally consistent acoustic-model updates.

References

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2. Micheyl, C., Harianawala, J., Schepker, H., Woodworth, L., Introwitz-Williams, M., Olson, M., and Iverson, S. (2023) Pro Fit Acoustic Model Optimization: A Better, Faster Fit. Starkey white paper.
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Author Biographies

Sarah R. Iverson, Au.D., CCC-A, is a Product Manager at Starkey, where she translates user needs into impactful product solutions. She currently supports the development of fitting software and mobile applications, ensuring they meet the evolving needs of hearing professionals and patients alike. Since joining Starkey in 2021 as a Research Audiologist, Dr. Iverson has applied her clinical expertise to guide data-driven decisions and competitive benchmarking, with a strong focus on audiological features that enhance patient outcomes. She earned her B.A. from the University of Minnesota and her Au.D. from Northwestern University.

Maddie Olson, Au.D. is the Manager of Clinical Product Research at Starkey, where she leads a team of audiologists dedicated to validating hearing technologies and ensuring exceptional performance and clinical benefit. Since joining Starkey as a Research Audiologist in 2021, Dr. Olson has spearheaded product validation studies and post-market studies to assess device efficacy over time. Her work supports the development of technologies that promote long-term, positive outcomes for hearing aid users.

Christophe Micheyl, Ph.D., joined Starkey in 2013 and is now a Senior Principal Scientist in the Starkey R&D Advanced Development team. He specializes in audiological applications of acoustics and hearing science for hearing aid research and development. He is particularly interested in clinically relevant innovations, with a focus on improving the hearing aid fitting process for hearing-care professionals and hearing aid users.

Michelle Hicks, PhD, Vice President of Research and Audiology, leads the Clinical and Audiology Research team at Starkey. She received her Ph.D. in Speech and Hearing Science in 1997 from Arizona State University. For the past 20 years, Dr. Hicks has held positions in clinical, academic, and industry settings, including as a professor at the University of Maryland and the University of Utah, teaching courses in Amplification, Pediatric Audiology, Psychoacoustics, Anatomy and Physiology, and Research Methodology. She has numerous publications and has presented at state, national, and international conferences on topics including hearing science, amplification, and tinnitus.