Test Box Verification of Vented Fittings: Development and First-stage Validation

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Overview

Hearing aid verification is considered preferred practice, and is normally completed in order to quantify hearing aid output in the ear canal of the wearer. This procedure facilitates accurate prescription and fine-tuning of the aided levels of speech, which in turn helps promote consistently beneficial hearing aid fittings. Hearing aid verification is typically completed with hearing aids worn on the ear, which is known as "real ear verification. Simulated real-ear verification (S-REM; aka Test Box Verification) is also possible, and uses corrections to predict the on-ear response. Such corrections have typically taken into account two factors: (a) the location of the hearing aid microphones (MLE); and (b) the Real-Ear to Coupler Difference (RECD). These corrections do not take into account the effects of vent-transmitted sound or of vent-loss. A new model for including venting in S-REM is now available, and has been validated in a large sample of adult ears. Implications for telepractice and pediatric audiology will be discussed.

Vent model development

The vent modeling uses two corrections: (1) the effect of unaided sound entering the ear canal through the vent (bypassing the hearing instrument) from the sound source, and (2) the effect of aided sound leaking out of the ear, through the vent. The values used were derived from published studies (Blau et al., 2008; Caprali, Cubic, Catis, Damsgaard, & Schmidt, 2019; Kuk & Keenan, 2006; Studebaker & Zachman, 1970). When the vent corrections are selected using the dome & vent type menus (Figure 1), vent corrections are applied to the S-REM measurement as shown in Figure 2.

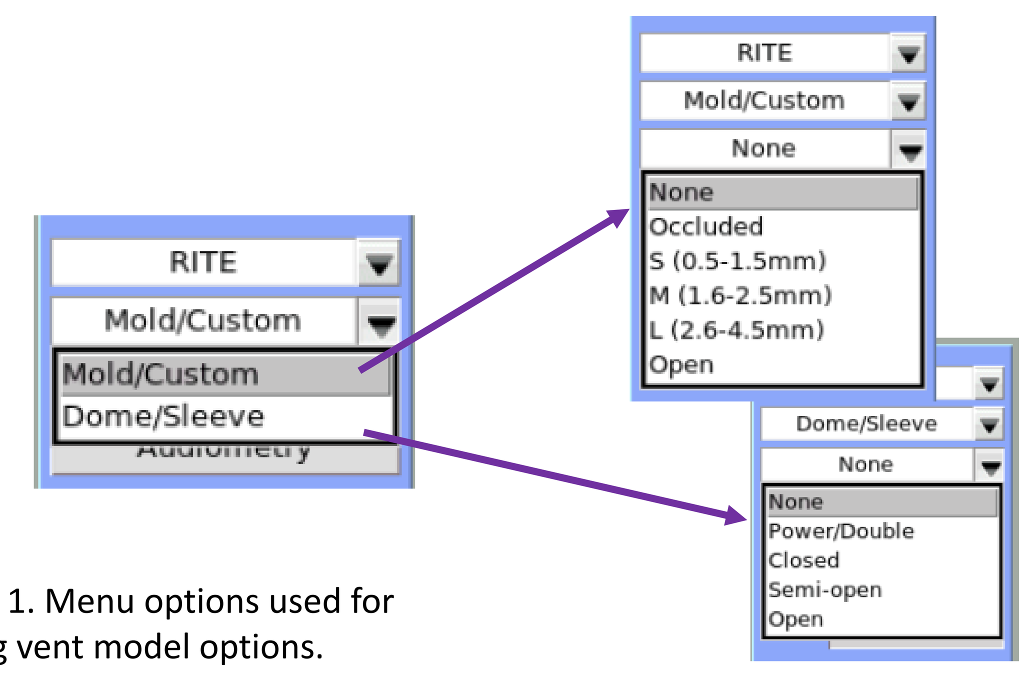

Figure 1. Menu options used for setting vent model options.

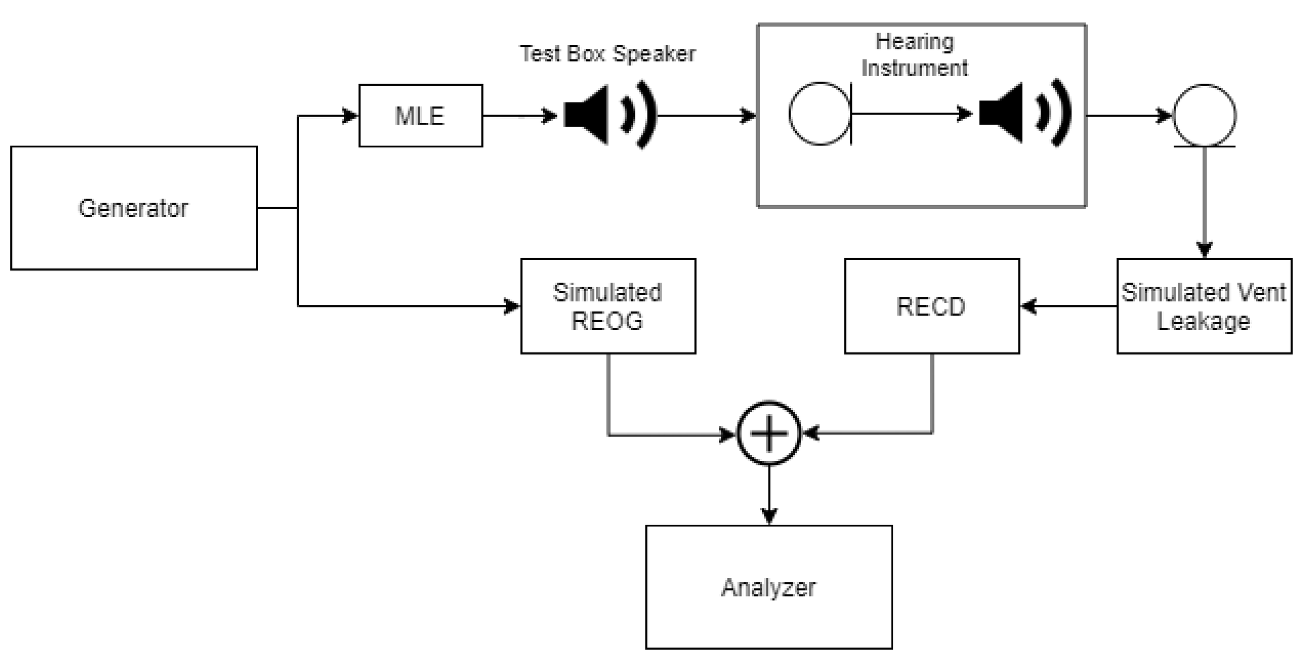

Figure 2. Conceptual illustration of vent model applied to simulated real-ear measurement.

Vent model evaluation

The vent model was evaluated by obtaining 110 hearing aid fittings that had previously been fitted using real-ear measurement (REM) over several research studies completed at the University of Western Ontario's National Centre for Audiology. The fittings were made using BTE with earmold, receiver-in-the-canal, and BTE with slimtube styles. All fittings were verified at three input levels, fitted to the DSL v5 target on a Verifit2 system, and incorporated measured Real-Ear to Coupler Differences. The hearing aids were reprogrammed to user settings and measured using both S-REM and Vented S-REM strategies (Figure 3).

Vent category	Number of ears
Closed	38
Power/double	14
Small	2
Medium	2
Semi-open	18
Open	36
TOTAL	110

Table 1. Number of ears included in vent model evaluation. Each ear was tested at three verification levels representing soft, average, and loud levels.

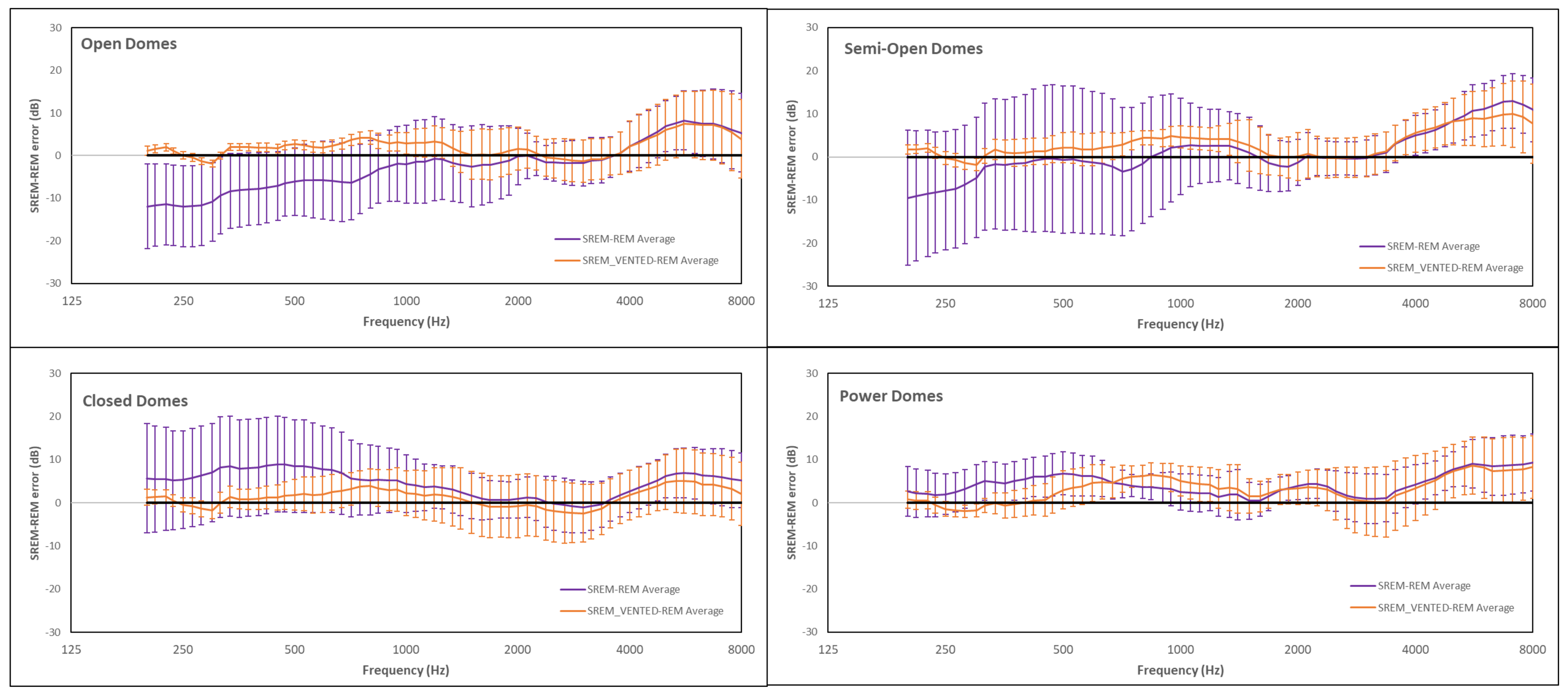

Figure 3. Mean and standard deviations of differences between REM and either S-REM (purple) and Vented S-REM (orange), across all test levels per frequency. Positive values indicate that S-REM over-estimated REM. Results are presented for four dome styles.

Analyses

Descriptives: Across frequency, level, and vent category, the S-REM measurement agreed with the REM measurement within 0.7 dB on average (S.D. 10.2 dB). This agrees well with previous studies. The Vented S-REM agreed with the REM measurement to within 0.9 dB on average (S.D. 7.1 dB).

Data reduction: The raw difference between REM and S-REM or vented S-REM results were computed (positive values indicates that S-REM over-predicted REM). The 73 data points for each verification were reduced to seven frequency bands corresponding to key frequency regions within the vent leakage portion of the model. Mean values within each band were computed for each measure. Differences between S-REM and Vented S-REM were also calculated to describe the changes associated with using the simulated vent model in verification (Figure 3).

Effects: Multivariate Analysis of Variance was used to evaluate the effects of S-REM type, frequency band, level, and vent category.

Significant effects included:

1. A significant interaction between S-REM type, frequency, and vent category ($F(12.1, 621.3)=15.7$, $p<.001$, $\eta^2=.235$).
2. Collapsed across level and frequency, measures in the Vented S-REM condition were significantly more accurate than S-REM for closed domes across frequencies, for power/double domes from 250 to 630 Hz, for semi-open domes at most frequencies, and for open hearing aids at all frequencies ($p<.05$). Caveats: (1) Improvements above the 1600 Hz band were small and not attributable the vent model, so may be spurious; (2) too few samples were measured for the custom earmolds to complete statistical comparisons, but descriptively they showed similar improvements to those with domes.
3. No significant effect of level; no significant interaction of level with the variables already discussed ($p>.05$).

Summary Results

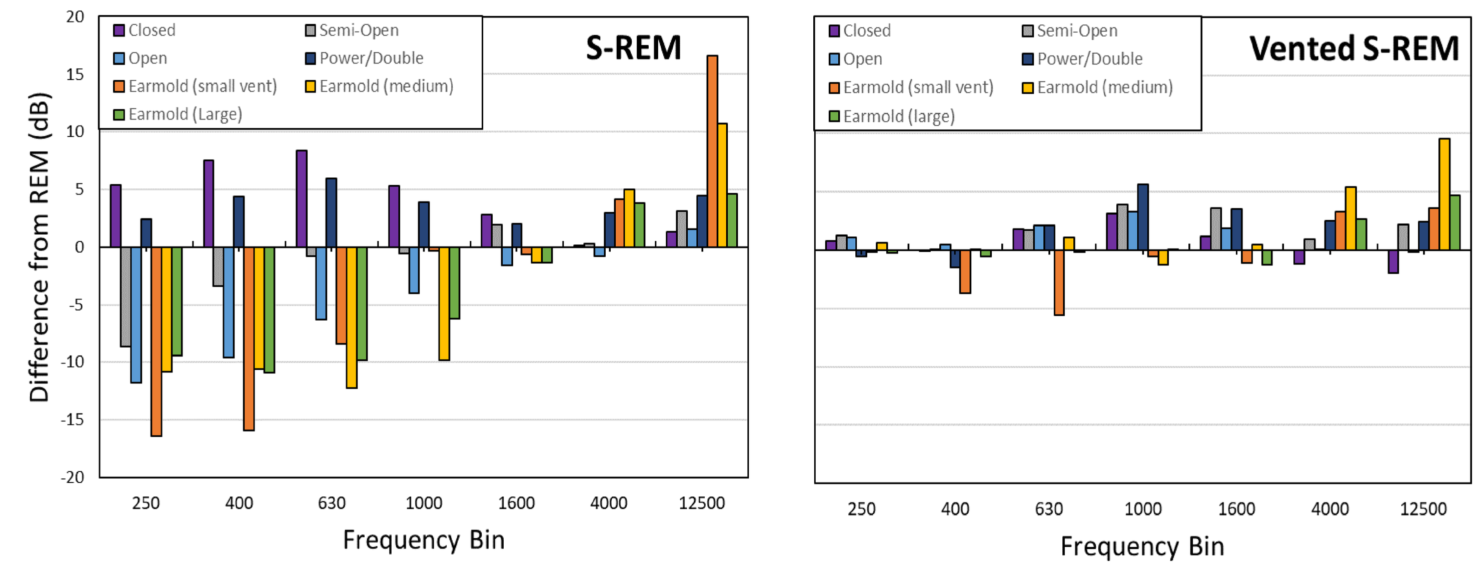

Figure 4. Mean differences between REM and either S-REM (left) and Vented S-REM (right), across all test levels, per frequency bin. Positive values indicate that S-REM over-estimated REM. Results are presented for four dome styles and for three earmold vent sizes.

Clinical Implications

Simulated Real-Ear Measurement (S-REM) was developed to provide a prediction of Real-Ear Measurement (REM), mainly for use with pediatric hearing aid fittings, which may have included little or no venting in the past. With increased use of open fittings in all ages, and with the need to provide telepractice, the clinical importance of S-REM across a wider range of applications has increased. This project defined a vent model and applied it within a clinical hearing aid analyzer. A sample of real fittings were re-verified both with S-REM and Vented S-REM, and compared to REM as the gold standard.

Without a vent correction, low frequency accuracy was poor particularly for open and vented styles, with S-REM both over-and under-estimating REM. Examination of individual cases relates this to hearing aid gain: fittings that have vents and low-frequency gain will have over-estimation in the coupler, while fittings with vents and little low-frequency gain will be under-estimated in the coupler. The dual-path vent model attempts to address both of these.

Both mean error and range of errors were reduced in the Vented S-REM condition for a wide range of hearing aid dome and earmold types. Particularly in the low frequencies, the average error was reduced by approximately 10 to 15 dB for semi-open, open, and vented earmold styles.

Summary: A new Vented S-REM option was developed that significantly improves the accuracy of S-REM approaches for many open and vented fitting types. This correction is now available for clinical use in some hearing aid analyzers. Further validation in pediatric hearing aid fittings may be required, although the low-frequency nature of the corrections used in the vent model are not expected to vary for pediatric versus adult ears as much as would other transforms such as the Real-Ear to Coupler Difference (RECD).

REFERENCES AVAILABLE UPON REQUEST

Western National Centre for Audiology

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