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Probe-Microphone Measurements with Body-Worn Instruments: Loudspeaker and Reference Microphone Effects

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Abstract

Probe-microphone measurements are typically made with behind-the-ear (BTE) and in-the-ear (ITE) hearing aids with the loudspeaker located at 0-degrees or 45-degrees azimuth at head level and the reference microphone positioned on the head near the hearing aid microphone. With body-worn instruments, these conditions may not accurately reflect in situ hearing aid performance. This study compared the real-ear aided response (REAR) and real-ear insertion response (REIR) for a body-worn hearing aid using the substitution method and an off-line equalization modified pressure method with three different loudspeaker locations (0 degrees and 45 degrees at head level and 0 degrees at body hearing aid level) and two reference microphone positions (over-the-ear [OTE] and next to the body hearing aid microphone). Results indicated that each of the responses was affected by changes in loudspeaker and reference microphone location. If the substitution method measured from 0-degrees azimuth at head level is considered to be the most realistic representation of hearing aid performance, the closest agreement with body-worn hearing aids was obtained with the modified pressure method when the loudspeaker was located at 0-degrees azimuth at head level and the reference microphone was located over the ear. If the clinician uses the modified pressure method and desires to approximate results with the substitution method, correction values are needed for REAR measurements but not for REIR measurements.

Key Words: Body hearing aid, probe-microphone measurements, real-ear aided response (REAR), real-ear insertion response (REIR), real-ear unaided response (REUR)

Probe-microphone measurements are currently receiving widespread application in hearing aid selection and fitting procedures. Measurements of the real-ear unaided response (REUR), real-ear aided response (REAR), and real-ear insertion response (REIR) are commonly obtained on behind-the-ear (BTE) and in-the-ear (ITE) hearing aids. Although these same measurements are sometimes made on body hearing aids and assistive listening devices (ALD) with a chest-location signal input, it is not clear if the same measurement procedures should be utilized.

Two measurement variables may be of importance to probe-microphone measurements of body-worn instruments: the location of the loudspeaker and reference microphone. The typical location of the reference microphone and loudspeaker has been chosen to accommodate BTE and ITE hearing aids. The loudspeaker is located vertically in the same plane as the hearing aid (typically at either 0-degrees or 45-degrees horizontal azimuth) and the reference microphone is positioned on the head near the hearing aid microphone. These positions may not be appropriate for a body-worn hearing aid or an ALD with a chest-location input, where the reference microphone is at a significant distance from the microphone of the amplification device, as the presence of the body can significantly alter the

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input to the hearing aid microphone (Erber, 1972).

The purpose of this study was to investigate the effects of loudspeaker and reference microphone location on probe-microphone measurements with a body-worn hearing aid. Measurements were made with three different loudspeaker locations (0 degrees and 45 degrees at ear level and 0 degrees at body hearing aid level) and two reference microphone positions (over-the-ear and next to the body hearing aid microphone). These measurements were compared to values obtained with a substitution method (0-degrees azimuth at head level), which were designated as the most valid representation of hearing aid performance.

METHOD

Measurements were made on a Knowles Electronics Manikin for Acoustic Research (KEMAR) placed in a large IAC double-walled sound-treated room. A Frye 6500 probe-microphone system was utilized for all measurements. A 50 dB SPL composite-weighted noise served as the stimulus. The loudspeaker was located 30.5 cm (12 in.) from the bridge of a KEMAR's nose in all but one condition, in which case it was located 30.5 cm from the microphone of the body hearing aid, which was at a mid-chest position. All aided measurements were made with a Widex S22 body hearing aid coupled to a DB-111 earmold simulator. Care was taken to insure that the hearing aid was operating on the linear portion of its input-output function. During all measurements, the probe tube was inserted in the ear canal to a constant depth calculated to be within several millimeters of the eardrum location. The probe tube was inserted through a custom-drilled vent parallel to the bore of the DB-111 earmold simulator.

REARs and REIRs were first obtained with a substitution method. In the substitution method, the sound field was equalized with the manikin absent. The KEMAR was then placed in the sound field at the exact location where equalization was accomplished. The loudspeaker was located at 0-degrees azimuth at head level. The reference microphone was not active during the probe measurements, thus allowing all head and body diffraction effects to be present. The results under this condition were deemed to best represent in situ performance, as it simulates the situation where the talker is directly in front of the person and all diffraction effects are present (i.e., a reference or controlling microphone has not, in effect, subtracted any of the naturally occurring diffraction effects).

The remaining measurements were obtained utilizing a different method of sound-field equalization. With the Frye 6500 probe-microphone system, this method can be described as a modified pressure method with off-line equalization. It represents a commonly used clinical approach. In this method, a reference microphone was located either over the ear or on the chest next to the body hearing aid microphone, and the sound field was equalized with the manikin present in the test position. When the reference microphone was positioned over the ear, the loudspeaker was located either at 0-degrees or 45-degrees azimuth at head level. For the chest location reference microphone position, the loudspeaker was located at 0-degrees azimuth elevated either to head level or chest level (directly in front of the body hearing aid microphone).

For the aided measurements, a differential comparison method was used in which the reference microphone was active and the probe-microphone system displayed the difference between the SPL measured by the probe-microphone and the reference microphone.

RESULTS AND DISCUSSION

In this study, the substitution method with the loudspeaker at 0-degrees azimuth at head level was considered the most realistic representation of hearing aid performance. Therefore, in order to observe the effect of differing loudspeaker/reference microphone locations, the REAR and REIR for each of the four modified pressure method conditions (0-degrees head level/over the ear; 45-degrees head level/over the ear; 0-degrees head level/chest; 0-degrees chest level/chest) were subtracted from the substitution response.

The results for the REAR are shown in Figure 1. Plotted in this manner, with the hearing aid settings unchanged, a positive difference value would indicate that the substitution method provided greater real-ear values than the test condition. Notice that the 0-degree head level/over-the-ear condition, represented by the solid line, provided the closest approximation to the substitution method. The deviations are less than 5 dB from 200 to 4000 Hz. Differences larger than 5 dB and sometimes exceeding 10 dB were observed with the other loudspeaker/reference microphone combina-

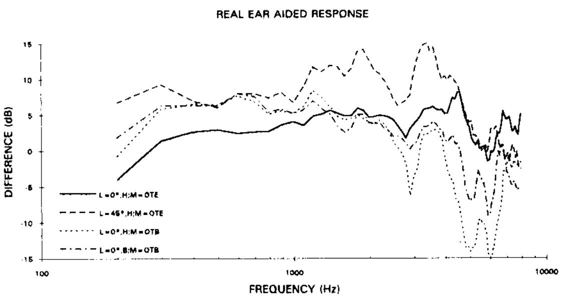

Figure 1 Real-ear aided response (REAR) differences (in dB) between the substitution method and a modified pressure method using different loudspeaker and reference microphone locations. Positive numbers indicate the REAR was greater with the substitution method. (L: loudspeaker location with head level [H] and body level [B]; M: reference microphone location with over the ear [OTE] and on the body [OTB].

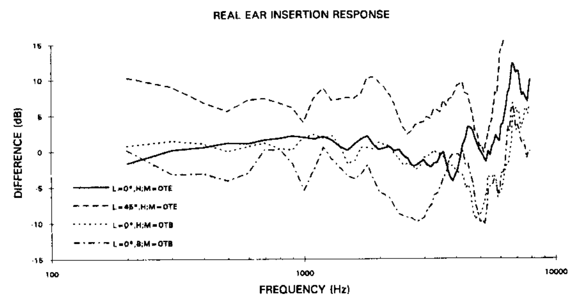

Figure 2 Real-ear insertion response (REIR) differences (in dB) between the substitution method and a modified pressure method using different loudspeaker and reference microphone locations. Positive numbers indicate the REIR was greater with the substitution method. (L: loudspeaker location with head level [H] and body level [B]; M: reference microphone location with over the ear [OTE] and on the body [OTB].

tions. If one desired to make corrections to the REAR obtained with the 0-degrees head level/ over-the-ear location to approximate the substitution method, then the values shown in Table 1 could be used. The values in Table 1 should be added to the obtained REAR to yield an accurate estimate of SPL in the ear canal that would be obtained with the substitution method.

The REIR results are shown in Figure 2. Again, the closest agreement with the substitution method was found with the 0-degrees head level/over-the-ear condition. The differences for this condition were within ±2 dB from 200 to 3700 Hz. Table 1 shows the corrections that would be appropriate for this condition. It is doubtful, however, whether most clinicians would consider these deviations to be of clinical significance and thus warrant the use of corrections. The largest differences were observed with the 45-degrees head level/over-the-ear and 0-degrees chest level/chest conditions.

Table 1 Correction Values to Be Added to a Modified Pressure Method Measurement to Produce Values Equivalent to Those Obtained with a Substitution Method

Frequency (Hz)	*REAR*	*REIR*
250	−2.5	−1
500	3	1
750	3	2
1000	4	2
1500	5	0
2000	5	0
3000	4	−1
4000	5	−3

In summary, loudspeaker and reference microphone location can affect probe-microphone measurement results with body-worn instruments. The measurement system (Frye 6500) used in this study allows the reference microphone to be moved as far away as the chest location. Even though on the surface the chest location might seem appropriate as it is close to the hearing aid microphone, our results would suggest that this is not the preferred location. If the substitution method with the loudspeaker located at 0-degrees azimuth at head level is considered the measurement that best represents actual performance, then the closest agreement for REARs and REIRs will be obtained with a modified pressure method when the loudspeaker is at 0-degrees azimuth at head level and the reference microphone is positioned over the ear. If the modified pressure method is utilized, corrections of approximately 5 dB from 500 to 4000 Hz seem warranted for REAR measurements, while REIR measurements can stand uncorrected.

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REFERENCES

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