Performance Variability of the Hearing Aid Telecoil

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The telecoil response of seven models of commercially available ear level hearing aids was examined with regard to effects of manipulating tone and automatic gain controls (AGC), increased magnetic field strength, and for intramodel consistency. Spectral analysis revealed variations of 6 dB or more across units of the same make and model for all conditions examined. Conversely, change in tone or AGC setting did not always result in expected change in output. These variations hold implications for predicting the effectiveness of telecoil use by hearing-impaired listeners not only for telephone communication, but also for use with assistive listening devices and for auditory training.

Although hearing aid manufacturers are required to provide comprehensive specifications for the electroacoustic performance of hearing aids, as yet no such requirements have been developed for evaluating the performance of a hearing aid telecoil. The protocol for evaluating a telecoil as stated in American National Standards Institute (ANSI) S3.22, Section 6.14 reads:

> With the gain control full on and the hearing aid set to "T" (telephone input) mode, the hearing aid is placed in a sinusoidal alternating magnetic field having an rms magnetic field strength of 10 mA/m at 1000 Hz and is oriented to produce the greatest coupler sound pressure level. The sound pressure level in the coupler is recorded.
>
> Tolerance — At 1000 Hz, the measured value of the coupler sound pressure level shall be within ±6 dB of the value specified by the manufacturer for the model. (American National Standards Institute, 1982, p. 9)

It is then noted that a curve of the sound pressure level in the coupler generated by the telecoil over the frequency range 200 to 5000 Hz with a 10 mA/m input may also be provided for informational purposes.

This procedure does not address several variables which may significantly affect the electromagnetic response of a hearing aid. With tolerance levels measured at only one frequency, a great deal of variability at non-test frequencies may be present within the telecoil response and still meet ANSI (1982) specifications.

With a behind-the-ear hearing aid in position on the head, there is a limited number of ways in which to orient a telephone handset to the hearing aid, none of which may be optimal. Gladstone (1985) observed an average difference of 21 dB SPL in the telecoil output as ear level hearing aids were compared in vertical and horizontal positions. Additionally, Holmes and Chase (1985) reported that, as hearing-impaired subjects using a telecoil moved the telephone receiver approximately one inch from the optimal telephone listening position, a decrease in sound pressure level of up to 15 dB was measured.

As with electroacoustic measurements, telecoil measurement also is performed at "factory settings"; that is, with tone set to N, saturation sound pressure level (SSPL) at maximum, and limiting off, as applicable to a particular instrument. The effect of tone and output controls on telecoil function would be useful for predicting user performance when other than factory settings are prescribed.

Investigators have primarily used induction loop systems when comparing a hearing aid's electroacoustic response to its telecoil response. Comparison has been made at various output, gain, and frequency response settings; with varying degrees of harmonic distortion; and with listeners who varied in word recognition ability (Calvert, Reddell, Donaldson, & Pew, 1965; Hodgson & Sung, 1972; Matkin & Olsen, 1970a, 1970b; Rodriguez, Holmes, & Gerhardt, 1985; Sung & Hodgson, 1971; Sung, Sung, & Hodgson, 1974; Van Tassell & Landin, 1980; Vargo, Taylor, Tannahill, & Plummer, 1970). The results of these studies have been interpreted to suggest that the telecoil provided greater low-frequency gain than the microphone, but the average gain of the telecoil circuitry never exceeded and was usually significantly less than the average gain of the microphone circuitry. The harmonic distortion of the electromagnetic response of the hearing aids was usually found to be below 20%. One conclusion typically mentioned in these and other studies is that the electroacoustic performance of a hearing aid cannot be used to predict its electromagnetic performance. The hearing aid dispenser, however, is only provided information regarding the telecoil capabilities at 1000 Hz with a 10 mA/m input. This would appear to limit severely the dispenser's ability to relate the effectiveness of a hearing aid's telecoil to a hearing-impaired listener's needs.

Less attention has been paid to telecoil performance when the hearing aid is coupled to a telephone receiver. Two reasons for this may include (a) difficulty in generalizing laboratory results due to high variability in magnetic field strength generated by individual telephone handsets and (b) difficulty maintaining a consistent input level when using magnetic leakage from the telephone handset. Several studies, however, have attempted to analyze the electromagnetic performance resultant from the magnetic leakage of a telephone (Holmes & Chase, 1985; Holmes & Frank, 1984; Lowe & Goldstein, 1982; Tannahill, 1983). Results of these studies have suggested that the upper and lower frequency response outputs are more restricted when the telecoil mode is chosen over the microphone mode. They have not consistently reported improvement in speech intelligibility for hearing-impaired listeners, which is the ultimate goal using a specific hearing aid-telephone coupling system.

Despite the lack of comprehensive standards for telecoil evaluation or an effective means to predict how a telecoil will perform, hearing-impaired individuals are now being fit with telecoil-equipped hearing aids, not only for telephone communication, but in conjunction with assistive listening devices, for auditory training, and with induction loop systems. Although modern technology has decreased the fortuitous magnetic leakage from telephone receivers through the use of fiber optics and electronic telephones, Public Law 97-410 has required that telephones be hearing aid compatible or be labeled as incompatible. The law also requires all coin-operated telephones and 10% of the room phones in hotels and motels to be compatible. Whether or not a telephone is hearing aid compatible is determined by the strength of the axial magnetic leakage from the telephone receiver. A field strength of 100 mA/m must be generated by a telephone to be termed hearing aid compatible.

While researchers have observed the effects of differences which exist between the performance of a hearing aid's microphone and that of its telecoil, few have concentrated on variations resulting from changes in the internal controls of hearing aids. The purpose of this study was to examine several variables which may affect the acoustic output of a hearing aid's telecoil. The variables examined included (a) tone control setting, (b) automatic gain control (AGC) setting, (c) magnetic field strength, and (d) intramodel consistency. Due to the lack of comprehensive standards regulating telecoil performance and the large tolerance accepted by ANSI S3.22 (1982), it was hypothesized that results would be inconsistent from instrument to instrument.

METHOD

An induction loop system with magnetic field strengths of 10 mA/m and 100 mA/m as measured at 1000 Hz by a magnetic field probe (Bruel & Kjaer MM0003) was used to assess the various telecoil responses of seven commercially available ear level hearing aids representing five hearing aid manufacturers. Input strengths were chosen to comply with the existing ANSI standard and to simulate the minimum axial magnetic leakage required for a hearing aid compatible telephone. The hearing aids were chosen to represent those which would typically be fit on moderately to severely hearing-impaired individuals, as these individuals benefit more from the additional amplification provided by telecoils than do those with mild or profound hearing losses

(Lybarger, 1982). A Sine Random generator (Bruel & Kjaer Type 1024) was used to produce a 125-10000 Hz sweep frequency input. The output of each aid was measured by attaching it to a 2-cc coupler which fed a one-inch pressure microphone (Bruel & Kjaer Type 4144). The microphone led to a preamplifier, then a sound level meter (Bruel & Kjaer Type 2218). The sound level meter was then coupled to a graphic level recorder (Bruel & Kjaer Type 2305) to chart the sound pressure level (SPL) output of the hearing aids. The frequency response of the induction loop system used to test the hearing aids was calibrated before and after each test session. Calibration resulted in a flat output response (±2 dB) over the test frequencies.

Each instrument was set and oriented within the magnetic field to produce maximum output levels at 1000 Hz as specified by ANSI S3.22 (1982). Aids were tested at each available tone setting, with AGC off, with AGC on, and at 10 and 100 mA/m. Frequency response curves generated by the telecoil circuitry of each hearing aid for each variable examined were superimposed for comparison. In addition, four hearing aids were selected for repeated testing using three different instruments of the same model. For all measurements, internal controls were set at factory settings with the volume control wheel in the full on position.

RESULTS

Effect of Tone Control

Figures 1 and 2 illustrate the change in the acoustic output of two representative hearing aids. The solid lines represent the broadest frequency response settings while the broken lines depict the effects of fully cutting back on the high and low tone control settings. As illustrated, the telecoil response of the first hearing aid demonstrated a 5-12 dB difference throughout the curve when the tone control was changed. Hearing aids #3, 4, 5, 6, and 7 were similarly affected. No measureable change was noted, however, in the telecoil response of the second instrument (Figure 2). When the controls were altered, both tracings overlapped entirely. Table 1 presents the range of differences for these hearing aids.

Effect of Automatic Gain Control

Figure 3 shows the effect of manipulating the AGC of hearing aid #7. In this instance, the broken line represents the telecoil response with the hearing aid set for minimum AGC. The solid line shows the result of fully activating the AGC. In this particular instrument, the change in the internal control did have an effect on the output. Of the four hearing aids tested which had AGC circuitry, all of the responses showed changes of 6 dB or greater as the AGC control was manipulated (see Table 1).

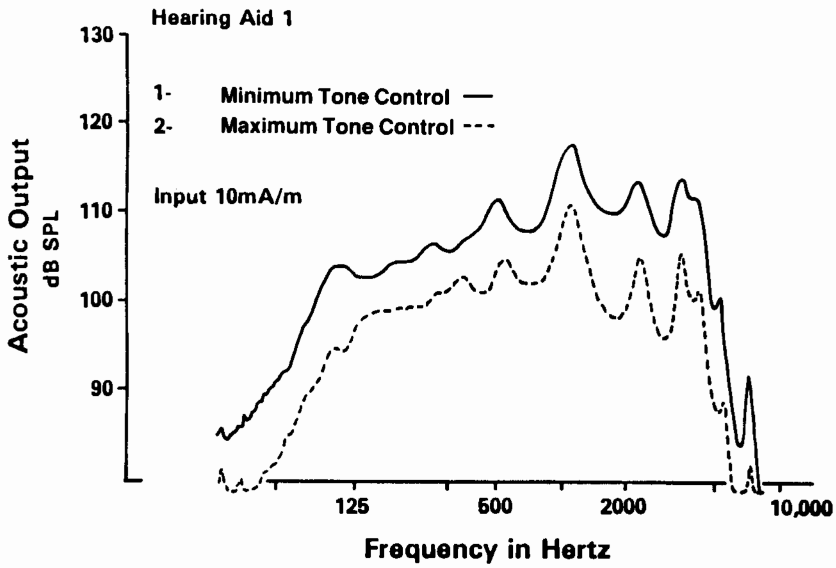

Figure 1. Variability in telecoil frequency response with change in tone control setting for hearing aid #1.

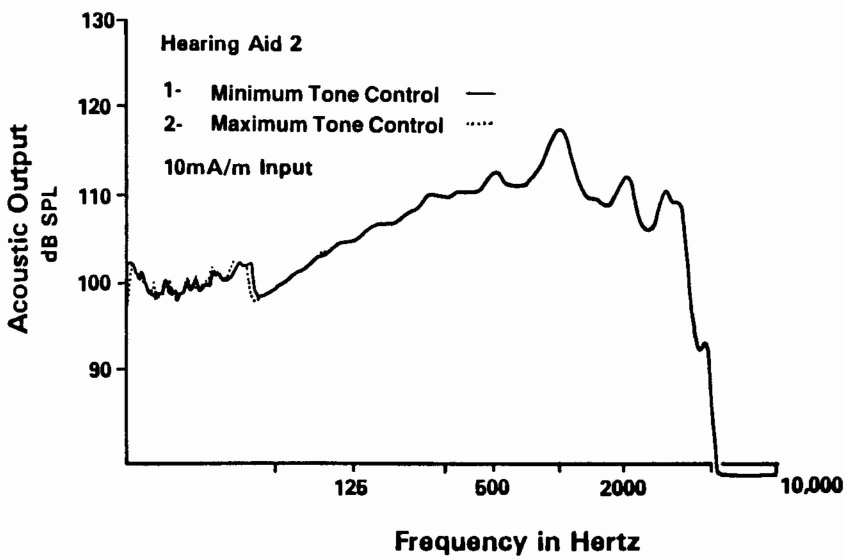

Figure 2. Variability in telecoil frequency response with change in tone control setting for hearing aid #2.

Table 1
Variation in the Telecoil Response of Hearing Aids with Magnetic Field Strength of 10 mA/m

Variable	Instrument Tested #1	#2	#3	#4	#5	#6	#7
Tone control setting[a]	5-12	0	4-13	0-2	16-23	11-16	0-19
AGC setting[a]	2-6	NA[b]	NA	NA	3-12	NA	6-11
Intramodel Consistency[c]	9	DNT[d]	9	8	DNT	17	DNT
Output at 250 Hz with 100 mA/m input compared to 10 mA/m[e]	16	0	11	5	11	33	4

[a]Range of output across 200-5000 Hz recorded in dB.
[b]Not applicable.
[c]Maximum variation in dB.
[d]Did not test.
[e]Measured in dB.

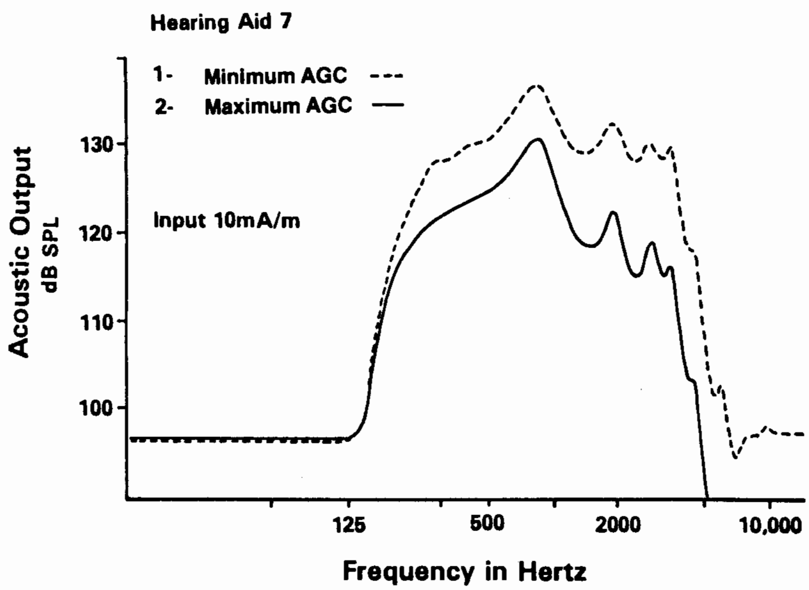

Figure 3. Variability in telecoil frequency response with change in automatic gain control (AGC) setting for hearing aid #7.

Effect of Magnetic Field Strength

Figure 4 illustrates the increase in low frequency gain typical of all the hearing aids tested in this study as the field strength was increased from 10 mA/m to 100 mA/m. Table 1 presents the difference in output levels at 250 Hz between 100 mA/m and 10 mA/m. The frequencies affected were predominantly below 1000 Hz, as most of the instruments were saturated with the 10 mA/m input above 1000 Hz. A similar effect due to change in magnetic field strength has been found by other investigators (Sung & Hodgson, 1971; Sung, Sung, & Hodgson, 1973, 1974). It should be noted that the outputs in Figure 4 would be within the tolerance now specified in ANSI S3.22 (1982).

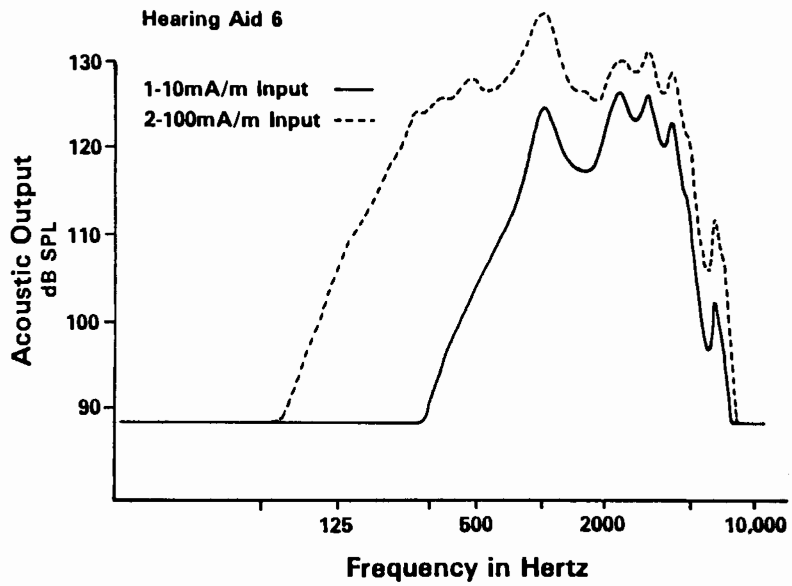

Figure 4. Variability in telecoil frequency response with increase in magnetic field strength for hearing aid #6.

Within-Model Variation

The tracings of Figure 5 represent the output of three units of hearing aid model #1 under identical test conditions. While the responses of the first and second instruments (shown as the solid and broken lines) appeared to be highly similar, the third aid (represented by the dotted line) had a weaker output level, especially in the low and mid frequencies. Not all seven hearing aids used in this study were examined in this manner. However, for three units of hearing aid models #1, #3, #4, and #6, the frequency response curve of at least one of the three units did not agree with that of the other two identical units;

that is, it differed from them by more than 6 dB at more than one frequency. Table 1 presents the maximum change in dB noted for each of the hearing aids tested.

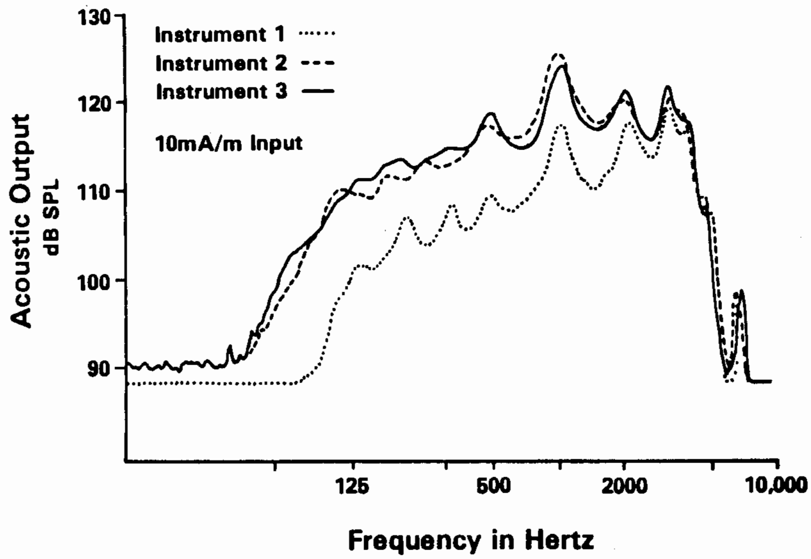

Figure 5. Variability in the telecoil frequency response for three units of hearing aid model #1.

DISCUSSION

Several variables affect the telecoil response of any given hearing aid: (a) selection of tone control setting, (b) use of AGC, (c) magnetic field strength, and (d) range of performance across instruments of a given model. While these variables appear similar to those affecting microphone performance of a given hearing aid, this is not always the case as illustrated in Figure 2 where no change in frequency response was noted with changes in the tone control of hearing aid #2.

Several hearing aid manufacturers have recently included telecoil frequency response curves with the required electroacoustic response information as suggested by ANSI. The usefulness of such measures would appear to be severely limited, however, when trying to predict the overall performance of a hearing aid's telecoil for the hearing-impaired consumer. The literature has repeatedly advised against making generalizations with regard to a given hearing aid's telecoil response pattern from electroacoustic specifications. However, the recognized method for evaluating a telecoil provides information only at 1000 Hz, which does not allow hearing aid dispensers to accurately assess the telecoil response of any given hearing aid. Additionally, an input level of 10 mA/m is specified, yet hearing aid compatible telephones must have an axial magnetic leakage of at least 100 mA/m. It has been shown that an increase in low-frequency gain is observed with an increase in magnetic field strength for hearing aids tested in an induction loop system. Although this has not yet been proved true for telecoil-telephone coupling, the possibilities of upward spread of masking and increased output levels should not be ignored. In addition to these problems, not all hearing aid dispensers may have the equipment needed to evaluate electromagnetic response.

From the results of this research, I would suggest several actions which could benefit both the professional community and the hearing-impaired conmer. The first of these would be the development of comprehensive standards for evaluating telecoil performance. The second would be standardization of the positioning and orientation of the telecoil within the hearing aid case to provide the hearing-impaired consumer with maximum signal strength when the telephone receiver is held in normal use position. The implementation of these suggestions would provide hearing aid dispensers a more effective means of predicting telecoil performance.

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