The hearing aid as warning signal receiver in noisy workplaces

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Since assessment of employability should take into account to what extent a hearing aid may restore hearing capabilities [1], this study was undertaken in order to test the possibility of the hearing aid induction coil to act as an effective receiver for sound warning signals in noisy surroundings.

Method

Experiments were carried out in a hemi-anechoic chamber using the acoustic head simulator designed by Kunov and Giguère [2]. This acoustic test fixture (ATF) approximates the physical dimensions and the acoustical eardrum impedance of the median human adult. The ATF includes a mechanical reproduction of the human circumaural and intraaural tissues. The acoustic isolation of the head simulator is greater than the bone conduction limitations to hearing protection.

The hearing aids were tested on the ATF, the left ear of which was equipped with the large KEMAR pinna. The sound pressure level at the output of the aid was picked up in a Zwislocki coupler fitted with of a condenser microphone (BK-4134) connected with a real time analyzer (BK-2123) by means of a preamplifier (BK-AO009).

Magnetic signal reception was tested using the Comtex and the Phonic Ear (System 4, model PE 475) FM transmitters, electrical signals serving as input. The induction coil of the Phonak Pico behind-the-ear (BTE) aid was used as a receiver. The response curve of the transmitters were assessed using a magnetic loop, a silhouette and a direct coupling. The Widex Q16 multi-programmable BTE aid was also used as a receiver to test the effect of the amplification curve setting on magnetic signal gain.

The influcence of background noises on masked thresholds was assessed for (a) the median hearing sensitivity of normal hearing males aged 55 years (ISO-7029), (b) a sloping high frequency hearing loss, ranging from 30 dB HTL at 2 kHz to 70 dB at 6 kHz, (c) a sloping loss ranging from 25 dB at 1 kHz down 75 dB at 6 kHz. Calculated attenuation values from a lucite earmold [3] were entered in *Detectsound*, a signal detection model [4] and masked thresholds were computed for a 85 dBA pink noise.

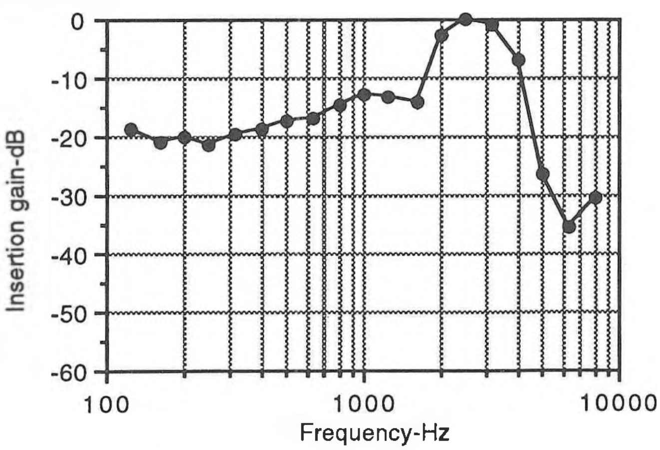
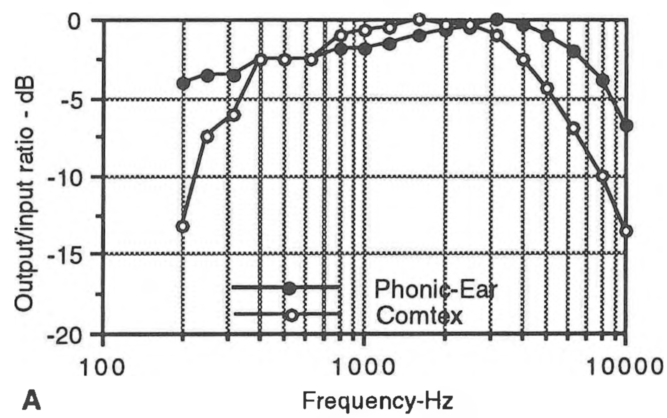


Figure 3. Insertion gain of Phonac PICO BTE aid measured on the acoustic test fixture.

Results

As a reference point, Figure 1 presents the insertion gain of the Phonak Pico BTE aid set for a high frequency hearing loss. Figure 2A depicts curves of the two FM systems tested. It can be seen that signal tranmission is not perfect. The Comtex system, in particular, serioulsy limits the passband of signal transmission. Figure 2B shows the corresponding frequency response when magnetically coupled with the Phonak Pico BTE aid. In the acoustic mode, the aid leads to a difference of 20 dB between the frequency of maximum gain (2.5 kHz: see Fig. 1) and the lower frequencies (e.g. at 200 Hz); in the magnetic mode, the difference amounts to 50 dB. This imperfection is partly avoided when the signals are received by direct audio input as shown in Figure 3. The response curve is closer to that from the normal acoustic mode, although there is still a systematic gain difference of 10 dB in the lower frequencies.

Such an effect can however be compensated by means of proper amplification settings. This is illustrated in Figure 6 with a multi-programmable aid. It can be seen that with a maximum bandwidth amplification, the passband is sufficient to cover a wide range of frequencies. This allows to transmit adequately sound warning signals in the range of 250 and 4000 Hz.



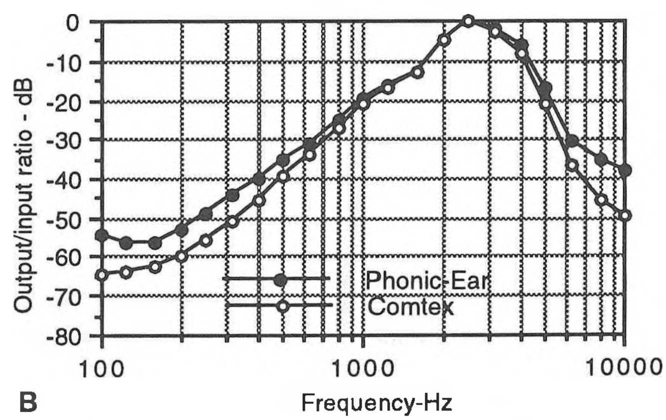


Figure 2. Frequency response of two FM transmission systems, measured (A) at the output of the FM receiver and (B) at the output of the Phonak Pico BTE aid operating in the magnetic mode.

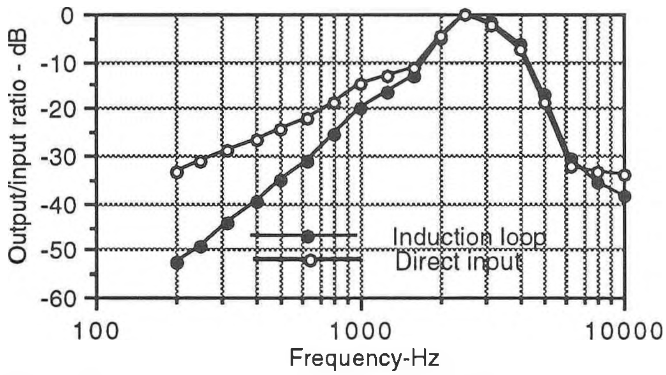


Figure 3. Frequency response of the Phonik Ear FM transmission system coupled with the Phonak Pico BTE aid through an induction loop and direct input.

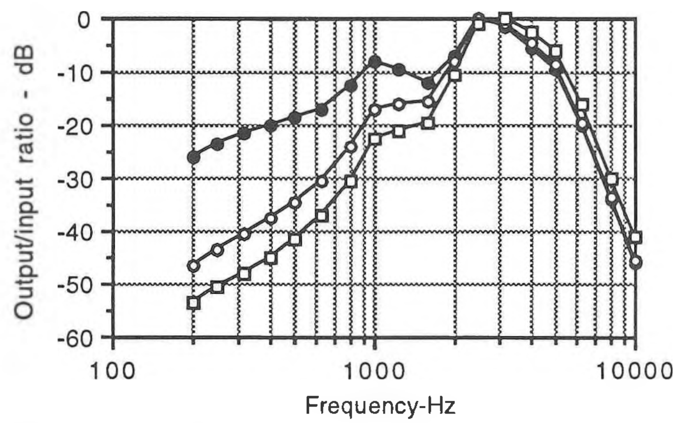


Figure 4. Frequency response curve of the Phonic Ear FM transmitter for magnetic signals measured at the output of a Widex Quattro BTE aid using direct input coupling; the three curves depict the response for different amplification settings.

A simulation of signal detection in noise was perfomed using our computerized model. It was assumed that a shell unvented earmold acted as an attenuator [3]. Masked thresholds were estimated for three audiometric configurations and a noise with a flat spectrum presented in a free-field at 85 dBA (Table I). It must be recalled that, in order to be detected and recognized, signals must be presented at 10 to 15 dB above the masked thresholds. The computer model used includes a +12 dB margin above the masked threshold [4]. Signal levels were computed so as to estimate the levels required at the output of the hearing aid. As shown in Table I, the resulting levels of recognition thresholds are all below 75 dB SPL. With high frequency hearing losses, the limiting condition is actually the absolute threshold at 3.15 kHz.

It is noticeable from Table I that the values of the signal recognition thresholds do not parallel the audiometric thresholds. This is mainly due to the poorer background noise attenuation in the lower frequencies provided by the earmold. As a consequence, the hearing aid setting for such a situation will strongly differ from that required for the normal acoustic mode. This calls for the use of a multi-programmable aid.

Table I. Audiometric thresholds and signal recognition thresholds (masked thresholds + 12 dB) in a background pink noise at 85 dBA, when attenutted by a lucite shell earmold of a BTE aid. The audiometric thresholds refer to normal male listerners aged 55 years (N) and to listeners with two degrees of sloping losses, S1 and S2. Signal recognition thresholds are computed at the output of the hearing aid. Bold characters refer to masked thresholds equal to absolute threshold.

	Hearing threshold levels - dB ISO			Recognition thresholds - dB SPL		
Frequency Hz	N	S1	S2	N	S1	S2
250	5	5	5	72	72	73
500	5	5	5	61	61	62
1000	6	6	25	59	60	61
2000	8	30	35	53	54	57
3150	16	50	55	47	**68**	**73**
4000	22	65	70			

Discussion

According to the present results, the attenuation provided by unvented earmolds and the amplification of magnetic or direct input signals by hearing aids can be combined to maximize the signal-to-noise ratio of sound warning signals transmitted to hearing impaired workers in noisy surroundings.This can help removing obstacles to the integration of people with hearing impairments in the workplace [5]. It can also represents a first step in occupational rehabilitation of hearing impaired industrial workers, that is a means to adapt to reduced auditory capacities in the workplace. Finally, the hearing aid could be used, as illustrated above, with normal listeners who need to receive sound signals in highly unfavorable acoustic conditions. This type of solution is potentially more effective than conventional earmuffs equipped with earphones [6]. The background noise attenuation would probably be higher and the response curve of the receiver would be finely tuned to both the sensitivity of the listener and the masking power of the attenuated noise.

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References

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