Directional hearing aid capabilities

By Norman S. Hillman, MBA

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This article's three-part purpose is to detail what the directional hearing aid can do, to define the terminology associated with directional aids, and, finally, to describe the operation of a directional hearing aid.

Expectations

The perception of the directionality of sound in the open out-of-doors is less complicated than it is indoors. When a listener is in an environment which does not have reflecting surfaces, sound arrives directly from the source; and a directional hearing aid will accept or reject the sound, depending on the location of the source. As one moves into locations which have reflecting surfaces, the sound from a given source will arrive both directly from the source and indirectly after reflection from the walls, ceiling and floor. In a room, reflected energy from a single sound source can arrive from above, below, behind, in front and the sides. In a large cathedral, the reverberation which results from the multiple reflections can give music a very pleasant effect, but make listening to speech quite difficult. In this situation, a properly designed and fitted directional hearing aid can make listening to speech easier by improving the ratio of direct (desired) sound to reverberant sound by 3 or 4 dB.

Terminology

AUTHOR'S NOTE: Certain terms which will be used in this article may have slightly different meanings when used in other context. Definitions of these terms as applicable in this article follow. If some of these terms seem obvious, we apologize, but we want to be sure that the concepts are clear, and that the definitions keep the concepts from being too general.

A microphone with a single sound inlet is able to sense the instantaneous air pressure of sound waves passing the inlet and will produce an electrical output voltage signal corresponding to the input. This type of microphone is referred to as a *pressure microphone* in this article, and is shown in cross-section in Fig. 1. A hearing aid containing the pressure microphone will be referred to as a *pressure hearing aid.* (This is the conventional type of aid, sometimes improperly referred to as a "non-directional" aid.)

Most hearing aid microphones have short, small diameter tubular sound inlets which are designed to be fitted with soft rubber or vinyl *extension tubing.* The extension tubing is tightly fitted to the microphone inlet so sound energy can be controlled. The extension tubing provides a pathway for the desired sounds from outside to reach the microphone and, at the same time, it isolates the microphone from sounds originating within the hearing aid case. The extension tubing often is part of the microphone suspension system which isolates the microphone from the case vibration and protects the microphone from mechanical shock. One of the most important functions of the extension tubing is to allow the hearing aid designer to have versatility in the selection of locations for sound inlets through the hearing aid case wall.

The *directional hearing aid* uses a two-inlet microphone which is referred to as a *directional microphone* in this article. One inlet leads to the *front acoustic cavity* of the microphone, and the other to the *rear.*

Operation

Recall that the directional hearing aid has both front and rear acoustical cavities. The terms "front" and "rear" relate the microphone cavities to the position of openings in the hearing aid case when mounted on a head. The two cavities in the microphone are separated by a very thin foil diaphragm. The diaphragm senses the difference between the instantaneous air pressures which impinge on its two surfaces. This pressure difference at the diaphragm causes it to move, and this mechanical movement is converted to an electrical output signal by the microphone. If the instantaneous air pressure in both cavities is the same magnitude and phase, the pressures acting on the diaphragm will cancel and so there will be no electrical output. The cross-sectional view of a directional microphone is shown in Fig. 2.

Notice that there is a *time delay acoustical network* associated with the rear acoustical inlet and cavity of the microphone. The design of the microphone considers, among other things, the dimensions of the front and rear acoustic extension tubes and the effective spacing between the inlets on the case of the hearing aid. If a sound wave arrives from the front, passing over the hearing aid on a head, it will pass the front inlet first and then pass the rear inlet of the hearing aid case. Or, if the sound wave arrives from behind the wearer, it will first pass over the rear inlet and then over the front inlet. The time delay system is designed so that the sound wave originating from the rear will reach the diaphragm through the rear acoustic network at approximately the same time as the sound wave reaches the diaphragm through the front acoustic network—so sounds originating from the rear will be substantially cancelled out. The cancellation will not occur with front originated sounds.

Most of us have seen what happens to the flow of water in a river when it approaches a wooden log which is stuck in the river bottom mud. The water flows around the log, creating ripples on the water, and may push the log out of the mud. If we were to think of the sound field as being similar to a free flowing river, then a person sitting in the sound field would be experiencing a situation where the sound waves would have to bend (or diffract) around the person while pushing against him (reflecting or being absorbed). Just as the water flows smoothly around a streamlined body (such as a boat) and bends when closely passing a blunt projection, sound waves move smoothly around an acoustically streamlined object and experience diffractions when closely passing a surface which has projections. The human head, neck and upper torso likewise affect passing sound waves by causing them to bend around the head, bounce off the shoulders and to diffract when passing each ear pinna. The changes to the sound wave caused by the presence of the human body will be somewhat different for sounds arriving from each direction and at each sound frequency. In some instances, the effect is to weaken the sound field, and in others is to reinforce it. At high frequencies, for example, the surfaces of the pinna act somewhat like the concentrating mirror to reflect the high frequencies toward a focal region over the ear canal and reinforce the sound that the ear senses.

If a hearing aid containing a miniature pressure microphone is placed in a free field (that is, in a sound field in a space free of reflections and diffractions) and is rotated about an axis which is perpendicular to the line passing from the hearing aid sound inlet to the sound source, the free field polar pressure response (shown as the solid line of Fig. 3) is obtained for frequencies below about 5 KHz. For these frequencies, the microphone sensitivity is essentially constant in all directions. The broken line of Fig. 3 shows curves developed with the same pressure hearing aid, but this time mounted on the side of the head of a manikin, and the entire manikin rotated about the same axis as the previous isolated instrument. Notice the profoundly different polar pattern which is observed. The hearing aid is no longer in a free field, but rather is in a field which is affected by the diffraction of sound waves around the head, and by reflections of sound waves from the manikin torso and neck and pinna. A pressure hearing aid mounted on the side of the head will usually exhibit maximum sensitivity for sounds coming from the side,

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Norman S. Hillman, MBA, is a marketing manager at Knowles Electronics, Inc., Franklin Park, IL.

as shown in the broken line polar pattern of Fig. 3. (This is one reason that a person wearing a hearing aid equipped with a pressure microphone will often turn the hearing aid side of his head toward a speaker when listening conditions are difficult.)

If a hearing aid containing a miniature directional microphone is placed in a free sound field, and the hearing instrument is rotated about an axis which is perpendicular to the line through the sound inlets of the hearing aid case to the sound source, the free field polar response typically will be as shown as the solid line in Fig. 4. This is obviously different from the response of the pressure hearing aid for these same test conditions. The broken line polar response shown in Fig. 4 for the directional hearing aid mounted on the side of the head shows less sensitivity toward the side and rear than does the similarly placed pressure hearing aid. The directional hearing aid located at the same position as the pressure instrument will exhibit maximum sensitivity for sounds coming more nearly from the front rather than from the side. This, together with the attenuated sensitivity to sounds from the undesired side and rear directions can make the sounds originating from the front easier for the wearer to understand. Directional hearing aids enhance the desired sound by reducing sensitivity to sounds arriving from directions which are less likely to provide desired information; they are not able to "reach out and capture the desired talker" with a narrowly concentrated, highly sensitive frontal performance. In fact, directional hearing aids cannot discriminate between two sound sources located in the same frontal direction. The forward rotation of the sound pattern (relative to a pressure hearing aid) permits the wearer to more easily watch the facial expressions and the lips of talkers, and, therefore, aids the wearer to obtain important visual cues during conversations.

The position of the hearing aid on the side of the head can affect the polar response since small changes in the location can change the amount of sound sensed in reflections from the pinna and shoulders, and in diffraction of the sound passing the pinna. There will be different combinations of these reflections and diffractions as the instrument is moved from the temple of the head toward the ear canal, and still different combinations if the same instrument is moved parallel to this path but only a few millimeters above or below that same path. The polar response will be slightly different at each frequency, and a polar angle which exhibits a low sensitivity at one frequency may show a somewhat higher sensitivity at another frequency. The hearing aid designer must consider not just whether his directional hearing aid will be a behind-the-ear style or an eyeglass style or an in-the-ear style, but where it will sit on the head. He must strive to find locations which will offer similar responses for a large portion of the human population. (If a patient has an ear shape which causes the directional hearing aid to be positioned so the line through the sound inlets will point skyward or down toward the ground, then the direction of low sensitivity at the rear will point downward or skyward, respectively.)

In a crowded indoor group situation (such as in a cafeteria or at a cocktail party), sounds come to the listener from multiple sources surrounding the listener; usually only those sound sources directly in front are desired by the listener. There are several things occurring in this situation. The loudest competing (undesirable) sounds will usually come directly from nearby talkers; those direct sounds which come from the sides and back will be rejected quite effectively by a well-designed directional hearing aid. The competing sounds which are generated by distant talkers and background noises arrive as predominently reflected energy, on the other hand, similar to the situation in the cathedral. A well-designed directional hearing aid will reduce these background noises by 3 or 4 dB. Thus,

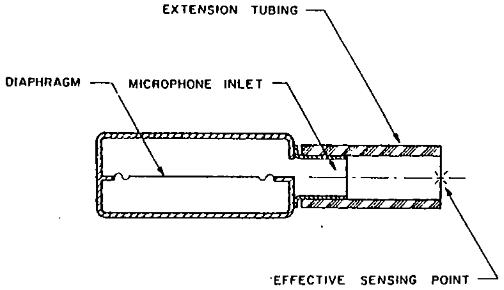

Fig. 1. Pressure type microphone cross-sectional view.

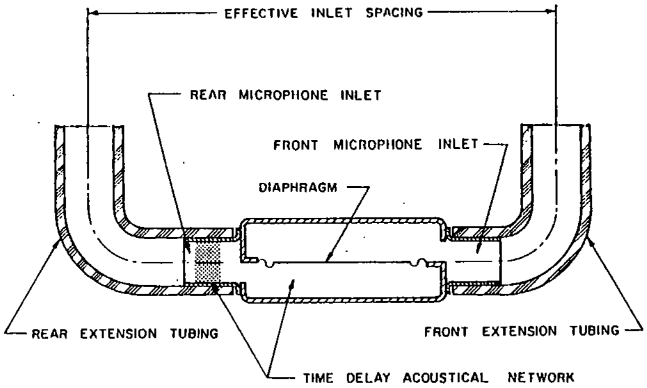

Fig. 2. Directional microphone cross-sectional view.

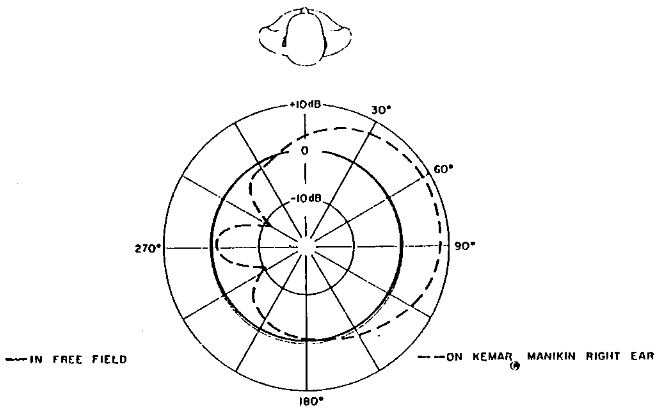

Fig. 3. Polar sensitivity pattern of pressure microphone at 2 KHz.

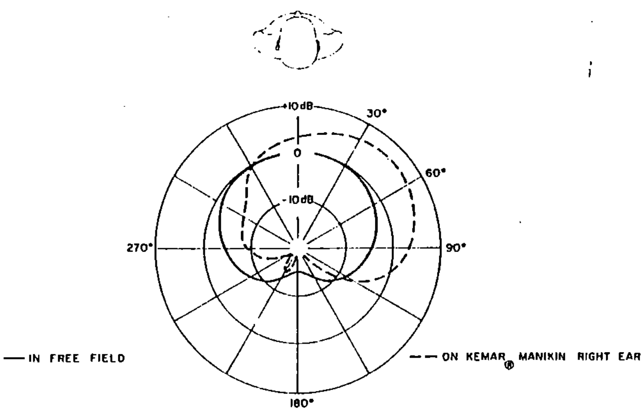

Fig. 4. Polar sensitivity pattern of directional microphone at 2 KHz. Adjusted for approximately cardioid free-field directivity. (Note: This is just one of many polar patterns which can be obtained.)

the total overall effectiveness of the directional hearing aid in this type of situation will depend on the relative energy from nearby and distant sources and can range from a few to many decibels of improvement.

In a small room, such as a typical individual's office, the sound reflections occur so quickly that the ear does not distinguish between the direct sound and the reflections. The subjective impression in small rooms is not that there is reverberation, but rather that there has been an increase in the overall loudness and some "coloration" of the sound. Although the increase in loudness will be somewhat greater with the pressure hearing aid (which senses the sound from both front and back about equally), a directional hearing aid with a slightly higher volume control setting can produce the same final loudness. Thus, the two types of hearing aids may sound quite similar in a small room. This perhaps explains reported difficulties in demonstrating directional hearing aids in a small room; this is an area which appears to have received little attention.

Atmospheric pressure changes, such as can occur when a major storm passes, or when one flies from sea level to a high mountain city (such as Denver or Mexico City) may be noticeable to some wearers of directional aids. The lower air pressure changes the effect of the internal time delay network, and this alters the directionality enough that an alert wearer can occasionally notice the change.

Since the directional hearing aid has two sound ports, it can be twice as vulnerable to wind noise as a single port pressure hearing aid. But most hearing aid designers minimize this noise by using smooth flow lines in the hearing aid case shape at the sound inlets so air turbulence is minimized.

The sound inlets of both pressure and directional hearing aids should be kept clear of dust and other occluding materials. Also, hearing aids should be removed from the head before using hair sprays to avoid getting the spray inside the aid.

Summary

In summary, the needs and the lifestyle of the user are an important factor in the degree of benefit and satisfaction that he or she can obtain from the directionality feature in a hearing aid. However, many hearing aid users have found that well-designed and properly fitted directional hearing aids can help them communicate with others in difficult listening situations, and with less fatigue and greater comfort. □

Bibliography

1. Berkley DA: Normal listeners in typical rooms: Reverberation perception, simulation and reduction. *Acoustical Factors Affecting Hearing Aid Performance* Studebaker GA and Hochbert I (eds) University Park Press, Baltimore, MD, 1980.
2. Burkhard MD and Sachs RM: Anthropometric manikin for acoustic research. *J Acous Soc Amer* 58:1, July 1975.
3. Carlson EV and Killion MC: Subminiature directional microphones, *J Aud Eng Soc* 22:2, pgs 92-96, March, 1974.
4. Damaske P and Wagener B: Directional hearing tests by the aid of an artificial head. *J Audiol Tech* 9:3, pgs 80-91, May, 1970.
5. Enger J and Decker TN: Directional microphones and sound field orientation of listeners. *Hear Instrum* 11:21-22, 1978.
6. Frank T and Gooden RG: The effect of hearing aid microphone types on speech discrimination scores in a background of multitalker noise. *Maico Audiological Library Series* Vol. XI, Report 5, 1973.
7. Knowles Electronics, Inc. Franklin Park, IL: *Technical Bulletins* A. TB-3: Effects of sound inlet variations on microphone response. July, 1976. B. TB-13: Effects of variation of supply voltage on sensitivity of BT microphones. April, 1975. C. TB-16: Electronic response shaping of directional microphones. October, 1975. D. TB-21: EB directional microphone application notes. December, 1980.
8. Knowles HS and Burkhard MD: Hearing aids on KEMAR. *Hear Instrum* 3:19-21,41, 1975.
9. Kuhn GF: Some effects of microphone location, signal bandwidth and incident wave field on the hearing aid input signal. *Acoustical Factors Affecting Hearing Aid Performance* Studebaker GA and Hochberg I (eds) University Park Press, Baltimore, MD, 1980.
10. Plomp R: Acoustical aspects of cocktail parties. *Acoustical* 38:186-191, 1977.
11. Rumoshosky JM: Directional microphones in ITE aids. *Hear Aid J* 4:11, 48-50, 1977.
12. Shaw E: The acoustics of the external ear. *Acoustical Factors Affecting Hearing Aid Performance* Studebaker GA and Hochberg I (eds) University Park Press, Baltimore, MD, 1980.
13. Studebaker GA, Cox RM and Formby C: The effect of environment on the directional performance of headworn hearing aids. *Acoustical Factors Affecting Hearing Aid Performance.* Studebaker GA and Hochberg I (eds) University Park Press, Baltimore, MD, 1980.
14. Studebaker GA and Hochberg I (eds): *Acoustical Factors Affecting Hearing Aid Performance* University Park Press, Baltimore, MD, 1980.
15. Sung GS, Sung RJ and Angelelli RM: Directional microphone in hearing aids. *Arch Otolaryngol* 101:316-319, May, 1975.
16. Wisniewsky WH: Measurement of the electro-acoustical characteristics of hearing aids. *J Audiol Tech* Part I: 9:5, pgs 152-170, September, 1970. Part 2: 9:6, pgs 198-212, November, 1970.

Additional reading

A lengthy list of recommended articles is to be found at the end of Technical Bulletin "TB-21: EB Directional Microphone Application Notes," published by Knowles Electronics, Inc., Franklin Park, IL.

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