Engineering Aspects of Assistive Device Technologies for Hard of Hearing and Deaf People

Charles A. Laszlo, Ph.D.
Department of Electrical Engineering
University of British Columbia
2356 Main Mall, Vancouver, B.C. V6T 1Z4
Ph: (604) 822-3956 Fax: (604) 822-5949 e-mail: laszlo@ee.ubc.ca

Hearing aids are widely recognized as important prosthetic devices which are essential to the everyday functioning of hard of hearing people. It is less generally understood that hearing aids alone cannot satisfy all the requirements of the hard of hearing population. This population consists of people of all ages, with varied occupations, interests, hearing loss and needs. Their common characteristic is that while they suffer lesser or greater degrees of hearing loss, their primary mode of communication is speech.

Another, much smaller, group are deaf persons who communicate primarily by sign language, and who do not or cannot make use of audible speech. Consequently, the technologies required by the hard of hearing and deaf populations are different in many ways, although some devices are used by both.

Technical aids have a profound importance in the life of hard of hearing and deaf people. Many of them need several different devices to function independently in the home, at work, and at leisure. Even those who ordinarily do not use hearing aids may require specialized devices to use the telephone or to communicate in groups. The large variety of devices used by hard of hearing and deaf people may be divided into four major groups: assistive listening devices (ALDs), visual communication aids, alerting and sound recognition systems, and telecommunication devices and systems.

Acoustical aspects are important in the engineering design and application of each of these systems. These aspects may be quite complex, and many environmental, architectural, technological, and user-dependent issues arise.

Hearing aids. To appreciate the problems and the need for assistive devices we must first examine hearing aid technology. The primary purpose of hearing aids is to improve speech communication ability. In general, hearing aids receive sound waves, modify them, and then retransmit them to some part of the auditory system. The original concept of hearing aids is based on the view that hearing loss may be characterized by decreased sensitivities from the normal at distinct frequencies of sound in the range of hearing. The aim of hearing aids has been primarily to provide amplification such that at these distinct frequencies the amplified sound counteracts the effect of decreased sensitivity to sound. If this can be accomplished then the aided ear is considered to be approximately as sensitive as the normal ear.

During the last 40 years this simple concept has been extended by the addition of various improvements, including amplification in selected frequency ranges, compression of the intensity range of sounds, noise reduction, directional sound reception, and rugged and reliable components.

While these developments have resulted in better performance and in improved speech comprehension for some hard of hearing people, the hope for the all encompassing solution has never materialized. The main reason for this is that sensitivity loss is not the only problem. Many hard of hearing people also suffer from loss of ability to discriminate the details of speech sounds. This loss of ability means that hard of hearing people cannot recognize important speech components resulting in the partial comprehension of speech.

In particular, the goal of creating a few types of instruments performing amplification and relatively simple processing able to improve speech comprehension for most, if not all, hard of hearing people has remained elusive. It is now generally accepted that the hard of hearing experience a great variety of different auditory performance problems, that no simple processing of the auditory signal will suffice, and that complex signal manipulation must be tailored individually to achieve the best possible improvement in speech comprehension. While rapid developments in digital electronics and digital signal processing provide the tools needed for complex signal manipulation, we are still lacking the physiological, medical and audiological knowledge that could guide engineering design to create hearing aids that can significantly deal with the comprehension problem.

This problem for hard of hearing people is vastly compounded by degradation of the acoustical signal between the speaker and the listener. Such degradation eliminates some speech clues, resulting in additional loss of speech comprehension. This makes hard of hearing people non-functional in many common listening situations where the acoustical conditions are less than ideal.

Assistive Listening Devices (ALDs) are communication systems that bypass the acoustic pathway between speaker and listener. In general, the input to such systems consists of one or more microphones connected to a transmission system. On the receiving end, specialized receivers are coupled to the listener's hearing aid or to earphones for those who don't normally use hearing aids.

Assistive listening devices acquire their input either from a microphone or from another signal source (e.g. television set). The objective is to ensure that the speech signal suffers no degradation due to echoes, distortion or any kind of environmental and instrumentation noise. Since the acoustical interference is the most difficult to control, the length of the acoustical pathway is minimized by placing the microphone as close to the speaker's mouth as possible. The rest of the transmission is non-acoustical until the very end where the signal is transduced and fed to the listener's eardrum. Different transmission methods are available that work well under appropriate conditions, although each has its limitations and drawbacks.

Induction loop systems consist of a number of turns of wire connected to a suitable amplifier. The loop is placed so that it will enclose the area in which hard of hearing users will be located, for example a group of chairs in a lecture hall. Many hearing aids can receive transmission from magnetic induction loops directly via built-in pick-up coils. Induction loops are simple and reliable, but require either permanent installation or the placing of wires around the room each time it is used. In addition, the magnetic field cannot easily be confined to one room, so that cross-talk and privacy problems arise.

Infrared systems designed for large areas consist of a preamplifier/control unit and an amplifier/driver that powers one or more arrays of infrared emitting diodes mounted on a tablet-like enclosure. In use, the speaker talks into the microphone, generating the signal that modulates the high-frequency carrier driving the infrared emitters. The infrared light then travels to individual receivers which convert the light back into an electrical signal, demodulate and amplify the sound component, and provide acoustical, magnetic or direct input to the hearing aid of the hard of hearing person. These systems work quite well, but they require careful installation (either permanent of temporary), governed by the need to provide even illumination by placing the infrared emission panels in appropriate elevated locations in the room. The control and driver units must be wired to each of the panels and in turn the microphone(s) must also be wired to the control. Small portable IR units requiring no setup, wiring or electrical connections to use became available recently. These devices combine the power source, the microphone, the electronics and the infrared emitters in one package. Placed in the middle of a conference table, or on a speaker's rostrum, these devices can serve up to 50 people.

FM communication systems usually consist of a microphone, an FM transmitter, and FM receivers which are worn individually by every user. Sometimes the microphone and the transmitter are combined into a "wireless microphone". These systems require minimal technical expertise to set up, and are very small, usually the size of a cigarette pack. A major problem with these systems is that they provide no security, as the signal may be picked up outside the confines of the room or meeting hall. In some applications this is not a problem, for example churches, but in many meetings, lectures, and presentations the possibility of being overheard is not acceptable. For this reason FM systems are not nearly as popular as they deserve to be, and because of the relatively small number of systems in use, their price remains high. Additional concern is to satisfy the sound reproduction quality requirements which are higher for hard of hearing than for normal hearing people. This poses some difficulty because of the practical requirement to keep the transmission bandwidth as small as possible.

Over the past decade much progress has been made by the hard of hearing in ensuring that adequate communication systems are provided at public gathering places. An indication of the growing acceptance and societal commitment to providing hearing access to hard of hearing people is that the Canada Building Code now requires that one of the above described systems be provided in any meeting room larger than 100 square meters.

Visual communication aids are important for both hard of hearing and deaf persons. "Captioned" television programs, for which the written transcription of the speaker's words can be made to appear on the screen using special equipment, are now commonplace.

Newer systems allow similar captioning of live speech at any meeting, lecture or event, and greatly enhance the ability of hearing impaired people to work in groups. These systems comprise of a manual input device, a computer system, and a means of displaying the typed text. The input device may be a standard keyboard, or some form of stenographic keyboard used by court reporters, for example. The computers and software used range from simple word processors to sophisticated translation systems. Displays can be television monitors or LCD overlays placed on overhead projectors.

These systems can overcome the problem of communication for those who cannot make any use of the acoustical method. Visual methods are also useful to complement auditory comprehension especially in cases where precision and understanding of detail is important.

The design of these systems must take into account the human factors involved in translating spoken words into writing. Typing operators must hear the speakers with clarity and, significantly, these normal-hearing people often require assistive listening devices described above. An important engineering challenge is to design equipment that does not generate any acoustical noise (e.g. keyboard clicks) or electromagnetic interference.

Alerting and sound recognition systems make it possible for many hard of hearing and deaf people to work and enjoy leisure in environments where important acoustical annunciator signals may be generated (e.g. telephones and appliance timers). The increasingly independent and mobile hearing impaired population also demands improved safety, and the ability to receive warning sounds (such as fire alarms) in noisy environments, and/or when sleeping or not wearing hearing aids. Emergency vehicle siren recognizers also have the potential to contribute to driving safety.

The engineering challenges in the design of such systems are formidable. Since annunciator and warning signals are not standardized, and are greatly modified by the time they reach the listener, automated and intelligent recognition of signals is required. This is difficult to accomplish at a reasonable cost. For this reason, the current generation of devices is not very sophisticated and relies primarily on the detection of changes in intensity and the presence of a few characteristic frequency components.

Telecommunication devices and systems include telephone and hearing aid interfaces, TTYs (sometimes also called TDDs for Telecommunication Devices for the Deaf),, and visual image transmission.

An important technology is inductive coupling between hearing aids and telephones, enabling hard of hearing persons to use the telephone without removing their hearing aids. This technology is not influenced by ambient acoustic noise, and overcomes the usually poor acoustic match between hearing aids and telephone receivers. The significance of this is that it makes the telephone system accessible to hard of hearing people, making it possible for them to hold jobs, to live independently, and to fully participate in family and community life. A major engineering problem is that newer telecommunication technologies may create extensive electromagnetic interference, causing major difficulties with inductive systems.

TTYs are miniature computer terminals operating through the telephone network. They use acoustic couplers to connect the unit to the telephone set. For hearing people who wish to communicate with a TTY user, a country-wide Message Relay Centre service is available. Calling this centre hearing and hearing impaired people are able to communicate with the help of an operator who both listens/speaks and types on a TTY. This provides tremendous flexibility and freedom.

Accessibility issues

Acoustical design to provide hearing accessibility for hard of hearing people is faced with the reality that acoustical treatment can only achieve limited objectives under a given set of circumstances. Secondly, even optimal acoustical performance may not be sufficient for hard of hearing people.

Consideration of assistive devices as integral parts of the communication design of a given space or environment may result in improved solutions to the satisfaction of all.

However, the design and deployment of assistive device technologies cannot be separated from non-technical hearing accessibility issues for hard of hearing people. Their objective, simply put, is to achieve and maintain communication under varying circumstances. The means by which this achieved is of secondary importance, provided that some conditions are met. First, the methods used must allow hearing accessibility comparable to that of hearing people. Second, technologies should be easy to use, and should require minimal technical expertise to operate. Third, there should be minimal additional financial burden on the user.

In practice, existing technological solutions to the hearing accessibility problem do not satisfy all of these conditions. Such shortcomings often stem not from engineering inadequacies, but from other sources.

The lack of standardization is a major obstacle. For example, assitive listening devices from different manufacturers (but using the same transmission method) are not necessarily compatible which each other. In addition, in the absence of performance criteria consumers (and even engineers) are left to make difficult purchasing decisions without adequate information. The result is market-place confusion, high prices, and dissatisfaction.

The lack of standardization also slows the development of effective universal systems that would allow a wide range of hearing aids and assistive devices to work together. In particular, the coupling of hearing aids and assistive devices remains a major problem that cannot solved in isolation from evolving telecommunication systems and the problems created by an increasingly polluted electromagnetic environment.

This is in turn has a profound effect on the ability and expectation of hard of hearing people to achieve reasonably universal accessibility. In view of the fact that now 10% of the population has a hearing loss that affects their auditory functioning in some circumstances, any lack of accessibility has a tremendous social impact. The hard of hearing consumer movement is a vital force in promoting hearing accessibility, and the occasional collaboration between engineers and consumer groups has been very productive.

Clearly, hearing accessibility is an area where social forces and technological capabilities are closely interlinked. In particular, heard of hearing people cannot achieve hearing accessibility without the collaboration of the rest of society. This requires not only societal willingness and resources to create and install various technical systems, but also changes in individual attitudes towards the manifestations of hearing loss.