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THE INFRARED LIGHT TRANSMISSION HEARING AID

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ABSTRACT

Recognizing the inherent weakness of the conventional hearing aid, we have developed a totally new design for hearing aids utilizing infrared (IR) light transmission. The hearing aid transmits the auditory message not as an acoustic wave, but as an infrared light beam. The invisible light beam carries the signal directly from a microphone near the speaker to the listener without any appreciable loss of level or fidelity, thereby providing true suppression of room noise. In preliminary tests, the IR aid has been shown to deliver intelligible sound under many noisy conditions where the conventional personal hearing aid is of little value. In this report, progress is reported in two related areas: *(i)* measurement of the hearing handicap of potential candidates for the IR aid, and *(ii)* engineering development of IR systems for personal and group hearing situations.

CONCEPT

Hearing Impairment

Hearing impairment is the most prevalent handicapping condition in America, with almost 10 percent of the total population debilitated by a hearing disorder (National Health Survey, 1975). The great majority of hearing impairments are due to neural dysfunction at the peripheral end organ of hearing, and are therefore uncorrectable with either surgical intervention or drug therapy. Among the aged, this sensorineural hearing loss is especially pronounced, with about 50 percent of the population over 65 years of age reporting hearing disorders that significantly interfere with everyday activities.

Many hearing impairments are subtle, and therefore difficult to detect. An auditory disorder may, for example, have little effect on reception of auditory communication under conditions of near total quiet, whereas in a background of moderate noise (as in a cafeteria) the disorder can have devastating consequences for speech reception. It is not uncommon for an individual to totally fail to recognize having a severe hearing impairment. The failure to detect a hearing disorder can have far-reaching consequences for the impaired listener. It is not unknown for an individual, for example an elderly person or a very young child, to be diagnosed as cognitively deficient, while the more fundamental problem of the hearing impairment is totally ignored. The implications of such a diagnosis for inappropriate treatment of the person are painfully obvious.

The major perceptual limitation of the partially hearing listener with sensorineural hearing damage is the inability to understand audible speech, especially when heard in a background of competing sounds. The listener often reports hearing the speech, but sounding muffled and garbled. This perceptual deficit has long been recognized by physicians and clinical audiologists, but only recently have there been attempts to describe in detail the properties of the auditory deficit characterizing the perception of everyday speech in a background of noise (Plomp, 1978; Leshowitz, 1977; Carhart and Tillman, 1970).

The clinical finding, that under conditions of background noise the conventional personal hearing aid often fails to improve speech reception, is perfectly consistent with the aforementioned difficulties in understanding speech reported by the listener with sensorineural hearing damage. Since the hearing aid provides indiscriminate amplification of both the wanted speech and the interfering noise, the clarity of the partially masked speech is often not improved by the prosthesis. Listeners often turn off the device in these noisy situations, and may even totally reject the hearing aid on the basis of these experiences (Federal Trade Commission Report, 1977).

Finally, our survey of the clinical literature reveals that debilitating hearing disorders may be even more widespread than had been realized (Suter, 1978; Skinner, 1976). One large class of listeners who heretofore have been considered to have normal hearing are listeners with near normal low-frequency hearing (say below 2000 Hz) and selective high-frequency hearing loss due to acoustic trauma or advancing age (presbycusis). Mainly from anecdotal reports from the clinic, it is known that this group experiences great difficulty understanding speech in noise. Moreover, these individuals would generally not be considered to have sufficient hearing damage to warrant a hearing aid—since their hearing loss in the low frequencies is within normal limits. Nevertheless, these individuals may be every bit as incapacitated auditorily under everyday noisy conditions as a listener with moderate to severe hearing loss (Courtois, 1975; Anianson, 1974).

The Conventional Hearing Aid

Forty years ago, when the electronic hearing aid was first introduced, it was thought that it would help the hearing impaired as much as eyeglasses helped the visually impaired. Unfortunately, hearing aids, which have never been altered in their basic design since their inception, have never lived up to these optimistic expectations. Hearing aids are miniature audio amplifiers placed in the vicinity of the ear. By increasing the volume of the hearing aid, the listener attempts to elevate the message's loudness until it is intelligible. In most everyday situations, however, ordinary background noise is present, and the inadequacy of the hearing aid usually becomes manifest. Under such noisy conditions, since both the unwanted background and the desired speech are amplified by the hearing aid, little benefit can accrue to the listener. It is only in those rare moments of near-total quiet that amplification provided by a hearing aid can perform its intended function.

The foregoing does not mean that the conventional hearing aid provides no benefit to the impaired listener. Indeed, in the absence of any prosthetic device, the listener might well be totally incapacitated by the hearing disorder. What is being asserted here is that, in many of life's most significant situations (for example, the classroom, the theatre, the restaurant, or the church) the conventional hearing prosthesis often does not provide sufficient assistance to the hearing-impaired individual.

The Close-Talking Microphone Hearing Aid

If speech reception in noise by many impaired listeners is to be improved significantly, the speech signal must be selectively amplified by the prosthetic device. In other words, the ratio of speech to noise level (or S/N) must be increased. A straightforward approach to solving this problem is to detach the microphone from the hearing aid and give it to the speaker. (Miller and Niemoeller, 1966). (This situation is analogous to a telephone connection.) In this way, the level of the speech at the speaker can be maintained with no loss, regardless of the distance separating speaker and listener. In spite of the obvious advantages of such an arrangement, the impracticality of a hard wire connection between speaker and listener is considered to be a major drawback and has led to rejection, under most circumstances, of the concept of a close-talking-microphone hearing aid.

Although the close-talking-microphone hearing aid has never gained acceptance by the hearing impaired, the benefits of close-talking microphone systems have long been known to audiologists in educational settings. Auditory training systems utilizing either hard wire connections to the listener's hearing aid, radio-frequency transmission, or audio magnetic loops have served as the basic communication system in schools for the partially hearing for many years. The audio loop, with audio-frequency magnetic oscillations suitable for detection by the "telephone pickup" available in many hearing aids, may be a useful system for many theaters, lecture halls, hotel meeting rooms, or other locations served by public address systems.

The virtues of auditory trainers have recently been recognized by the general public. In what may turn out to be a historic decision, made in response to a petition from the Buffalo Philharmonic Orchestra, the Federal Communications Commission authorized the use of auditory training devices for people with impaired hearing at public concerts. The ruling waives the present restriction limiting auditory trainers to school instruction. Supporting this ruling, a spokesman for the National Endowment for the Arts stated that ". . . we should issue a rule-making (procedure) to allow widespread use of these devices in the concert hall."

The goal of the present work is to extend this proven approach of transmission from a close talking microphone to a wide variety of communication situations, not only for listeners with significant hearing loss, but also for listeners with moderate or seemingly insignificant hearing loss. With the advent of low-cost, reliable technology for infrared light transmission of audio, much broader applications of close-talking-microphone systems now appears to be feasible.

THE INFRARED LIGHT TRANSMISSION HEARING AID

Having analyzed the inherent shortcomings of existing hearing aid technology, we have developed a totally new design for the hearing aid. Borrowing from recent breakthroughs in light transmission communication, we have built, in prototype form, an infrared (IR) light transmission hearing aid (Fig. 1).

The experimental prototype transmitter shown in Figure 1 is about the size of a pack of cigarettes. It was built at the Institute for Perception Research in the Netherlands, while the author was spending a sabbatical year at the Institute. It contains a microphone, amplifiers, and five infrared light emitting diodes (LED's), three mounted in small reflectors which face forward, and two pointed upward. The five LED's are mounted so that the light signal is emitted in practically

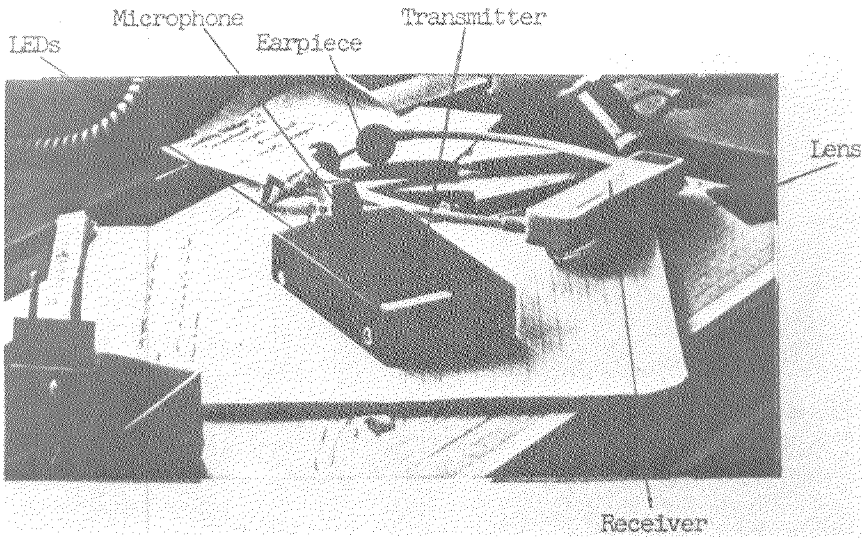

FIGURE 1.—The IR hearing aid prototype. The rectangular dark object is the transmitter with attached close-talking microphone. The receiver, with curving arms ending in earpieces, is behind and to the right.

all directions, permitting reception of the signal from almost any position in the room. The listener does not have to maintain a direct line-of-sight in the room enclosure in order to receive the transmitted IR signal.

The electronic circuitry is designed for high fidelity, having a frequency response extending to at least 15 kHz. The transmitter circuitry uses the audio signal to frequency-modulate a 95-kHz carrier frequency which is transmitted by the LED's to the listener.

The prototype receiver (Fig. 1) is commercially available from Sennheiser Corp. of Germany, and can be ordered at most stores specializing in audio equipment. It has a photodetector, mounted behind a hemispherical lens which is slightly filtered to reduce interference from ambient light. The received infrared light signal is transduced into an electrical signal which is ultimately led to the earpiece.

Block diagrams for the transmitter and receiver are shown in Figures 2 and 3.

Departing from the traditional design of a hearing aid, the IR aid consists of two components: a microphone and transmitter given to the speaker, and a receiver given to the listener. In the transmitter, the speaker's voice (dominating over the room noise) is first transformed into an electrical signal by the microphone. This electrical signal is then used to modulate an invisible IR light beam produced by

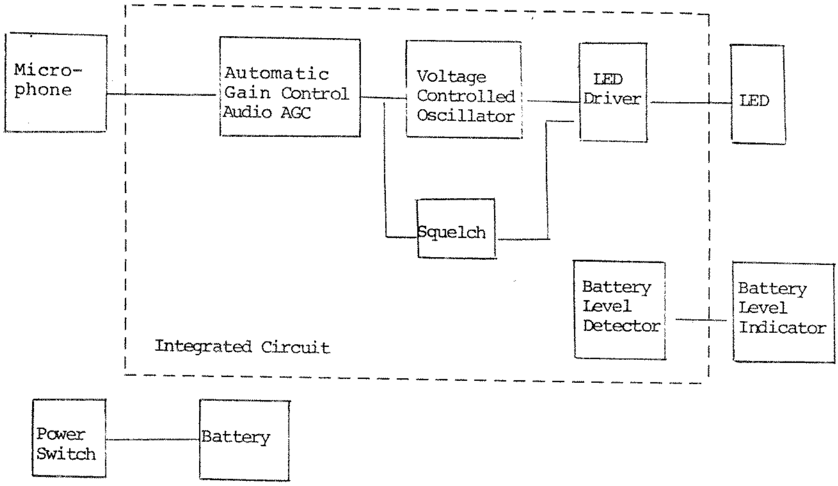

FIGURE 2. — Block diagram of the transmitter.

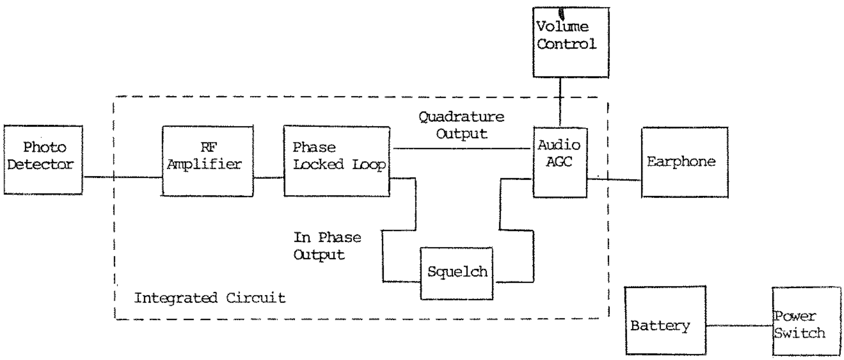

FIGURE 3. — Block diagram of the receiver.

each of the light-emitting diodes (LED's). The modulated light carrying the auditory message is then received by the listener (free from significant background sounds), where it is converted back into an electrical signal, which is amplified and used to drive the listener's earpiece.

It is to be emphasized that the aforementioned configuration of the IR hearing aid, utilizing a single transmitter, can accommodate one, or at most two or three, speakers. The system, then, is impractical in listening situations where there is a roomful of potential speakers, each seated around the perimeter. More elaborate arrangements, incorporating multiple transmitters, could be devised to handle group conferences or conversations, but they would be too unwieldly to be of very much practical value.

Using the IR system to amplify selectively the speech signal is equivalent to suppressing interfering background noise. Thus, at a typical speaker-to-listener distance of two meters, the effective reduction in background noise is between 10 and 15 dB. For many hard-of-hearing individuals, this reduction is adequate to permit good reception of the speech message.

In summary, the IR hearing aid utilizes light transmission of sound from a microphone near the speaker in an attempt to overcome the interfering effects of background noise. The IR aid transmits the auditory message imposed on an infrared light beam rather than as a acoustic wave. With this system, a "hard wire" (provided by the invisible beam) carries the auditory signal directly from the speaker to the listener. The net effect of light transmission, then, is to bring the message from speaker to listener with neither the loss of level attendant to propagation of sound in space nor the addition of background sound which would be picked up indiscriminately by the conventional hearing-aid microphone on the body of the hard-of-hearing user.

ALTERNATIVE SYSTEMS FOR IMPROVING THE SPEECH-TO-NOISE RATIO

From an analysis of the problems faced by the hearing-aid user, one is forced to conclude that for many, perhaps most, listeners with significant sensorineural hearing damage, an effective auditory prosthesis must selectively amplify the desired message. It should be emphasized however, that the close-talking-microphone hearing aid is not the only system capable of improving the speech-to-noise ratio. Indeed, the need to suppress unwanted background noise has been recognized by hearing-aid manufacturers who have introduced aids containing microphones with directional pickups. Unfortunately, the miniaturized package of the conventional hearing aid is largely incompatible with this approach. As a result, even under the most optimal listening conditions, it has been found that the S/N can be improved by at most one to two dB. Other, more sophisticated, approaches to enhancing the desired signal through digital signal processing techniques are being pursued actively, but are probably years away from practical application.

Under the present state of the art, it appears that the only feasible method of significantly enhancing the relative level of the speech signal is to employ a close-talking microphone system. Of the available close-talking systems we have examined, IR light transmission is, we feel, the system of choice. In order to understand the basis for this conclusion, it may be helpful to compare the IR system with its principal competitor, the FM radio broadcast system.

1. For a personal hearing aid, it is essential to confine the transmitted message to a single small enclosure. This is very difficult to accomplish when using radio waves. Light signals, on the other hand, are restricted by any opaque partition, thereby insuring privacy and greatly reducing risk of interference.

2. Pollution of the air waves with a multitude of radio broadcasts created by hearing-aid users is totally impractical.

3. Regulations for FM radio use imposed by the Federal Communication Commission would provide an almost insurmountable obstacle. (In Europe, FM radio transmission is precluded in that there are at present no available radio frequencies—not even for auditory trainers.)

4. In recent side-by-side listening tests comparing the fidelity of IR light-transmission and radio-broadcast auditory trainers, made at the Philips Corporation by the author and several Dutch colleagues, it was found that light transmission is superior.

5. Engineering estimates of the reliability as well as the cost of the two competing systems show that light transmission is again the system of choice.

For these practical considerations, we have concluded that IR light transmission is the preferred approach for implementing the close-talking-microphone hearing aid.

MEASUREMENT OF AUDITORY HANDICAP

The Masked Speech Intelligibility Threshold (MSIT)

At present there is no standardized quantitative measure of the impaired listener's capacity to understand speech under everyday conditions of competing background noise. Thus, we feel, there is a pressing need for an audiometric measure for predicting whether a hearing aid recipient will derive appreciable benefit from a prothesis under everyday conditions. To that end we propose, as a quantitative index of speech perception performance, the Masked Speech Intelligibility Threshold (MSIT). The MSIT is the average level of speech relative to the background (i.e., S/N) required for a listener to achieve 50 percent discrimination performance on a standard word list. Because the MSIT is related to the listener's capacity to understand continuous discourse, the MSIT also provides an objective, though indirect, measure of a listener's ability to participate in normal conversation.

For a more detailed specification of the MSIT, the reader is refered to Leshowitz (1977) and Leshowitz and Lindstrom (1978).

How the MSIT can be used to characterize a listener's auditory handicap in understanding speech under everyday circumstances is illustrated by the following example. From previous work (Kruel et al., 1968; Leshowitz and Lindstrom, 1978), we know that normally-hearing listeners have an MSIT (measured in the laboratory) of about 0 dB, whereas a listener with sensorineural hearing damage typically has a MSIT of about 10 dB. Thus, in agreement with the clinical observations of the difficulties experienced by the listener with sensorineural hearing damage in perceiving speech in noise, laboratory measurements of the MSIT indicate that when the background level is within 10 dB of the speech, the impared listener will begin to fail to understand the speech message. Normal listeners, on the other hand, can tolerate, on the average, another 10 dB of noise before oral communication breaks down. This deficit, combined with the observation that in many everyday situations the speech-to-noise ratio is in the order of 0 dB (Gardner, 1971), suggests that many impared listeners will be severely incapacitated in their ability to carry on oral communication during a large part of their "acoustical day".

Screening of Hearing Aid Candidates

The MSIT does not only provide an estimate of the listener's speech perception handicap; it also indicates the degree to which an auditory impairment can be corrected by a hearing aid. Consider the hypothetical listener with a uniform hearing loss of 50 dB, measured in quiet, and an MSIT of 10 dB measured in the presence of a moderate competing background (cafeteria) noise. While amplification provided by the conventional hearing aid may be expected to overcome the hearing impairment in quiet, there is no assurance that the aid will prove useful in noise. Indeed, on the assumption that this listener requires greater relative signal strength than the normally hearing individual, the aid may well be totally useless in a noisy situation since it does not selectively amplify the signal. Even with the listener placed at a comfortable listening distance (say 2 meters from the speaker) where the level of the speech and noise are each 65 dB (i.e., S/N = 0 dB), laboratory findings and clinical experience indicate that the impared listener will be unable to understand the spoken message — either with or without the conventional hearing aid.

However, the MSIT measure indicates that our hypothetical listener will derive considerable benefit from the IR hearing aid. Recall that the IR aid delivers to the listener substantially the full strength speech signal measured at the lips of the speaker. In the present illustration, the speech at the speaker's lips is about 75 dB SPL, and since the background noise can be considered to be of uniform level (i.e., 65 dB SPL) throughout the room, the speech-to-noise ratio at the speaker will be +10 dB. But what is most important is that with the IR aid, the S/N at the listener's earpiece is also +10 dB, which is 10 dB greater than measured for the conventional hearing aid. According to all indications, this increment in the S/N is sufficient to permit good reception of the speech message by the impaired listeners. The conclusion reached, then, is that this listener is a good candidate for the IR aid.

Data collected in our laboratory indicate, moreover, that the vast majority of listeners with sensorineural hearing damage have MSIT's that are usually within 15 dB SPL of the normal hearing listener, and therefore all should experience major benefits from the IR aid. Verification of this hypothesis was obtained in a recent study conducted in our laboratory, in collaboration with Dr. John Franks of The Communication Disorders Department at Arizona State University. (Those presently unpublished data are available upon request.)

Measurement of Speech Intelligibility

The effectiveness of the IR hearing aid was assessed by comparing its performance to that of the conventional personal hearing aid on a sample of 119 hearing-aid users. The IR prototype hearing aid evaluated in the study was a modified version of the IR transmitter and receiver manufactured by the Sennheiser Corp. for transmitting TV audio. A microphone was added to the transmitter so that speech could serve as input to the system. Under standard conditions of hearing-aid evaluation, word discrimination was measured with the listner's personal hearing aid and with the IR device.

In the first phase of the study, the subjects' unaided speech reception threshold (SRT) and word discrimination score (PB-50's presented at 25 dB SL) were measured. These scores served as the reference for comparison with aided performance. A soundfield was used in the second phase of the study in order to compare the performance of the listener's personal hearing aid with the IR device. Threeee measures of performance were used: PB score in quiet; PB score in noise; and masking level required to mask spondaic words presented at the PB presentation level.

The results showed a clear superiority of the IR device over the personal hearing aid, under noisy conditions. Whereas in the quiet, word discrimination scores using the IR aid were almost identical to scores obtained with the personal aid, in moderate noise there was, on the average, a 55 percent improvement in performance with the IR aid over the personal hearing aid.

From a comparision of the masking levels for the two conditions, it was noted that, using the IR aid, the speech source could be reduced in level by 14 dB and still maintain the performance achieved with the personal aid. Those listeners with pure sensorineural hearing loss showed the largest improvement in S/N (16.5 dB on the average) using the IR aid. These results constitute empirical confirmation of the IR's capacity to enhance the S/N under noisy conditions often encountered in everyday listening situations.

Measurement of Acceptability of the IR Hearing Aid

Although the aforementioned findings demonstrate the high quality of speech transmission delivered by the IR hearing aid, they do not bear directly on the acceptability of the IR hearing aid. In other words, we have no assurance that impaired listeners would use the more cumbersome two-component IR hearing aid were it made available. In order to determine whether hearing-impaired listeners find the IR hearing aid acceptable, subjective impressions of the IR aid were examined in a second study.

Individual reactions to the IR hearing aid were elicited from 17 hearing-impaired listeners in a preliminary evaluation study. Listeners were asked to use the IR prototype while listening to radio or television. The listeners were then requested to assess the performance of the IR device by completing a 15-item questionnaire. All items on the questionnaire were positively polled so that a score of 5 represents greatest satisfaction and a score of 0 least satisfaction. Some representative items on the questionnaire are the following: "This device greatly improved my ability to understand the speech on TV; I was not embarrassed wearing this type of aid; Noise in the room did not interfere with my understanding of TV."

In all, these was a total of 227 responses to questions about the IR device. The mean score per question was 4.3 (out of a possible 5), indicating high satisfaction and acceptability. A few questions were not answered by all subjects, most notably these questions dealing with a comparison to other personal hearing aids. These questions may have been inappropriate in that not all listeners had previous experience with a hearing aid. Out of the 227 responses, only one subject used a 0 score; this score was given to a question about his family's potential response to the IR device. Except for this one response, the lowest score given to any question was a 3. This question was concerned with cosmetic acceptability, suggesting that the greatest objection to the current prototype may be its inconvenient and cumbersome form.

The majority of responses to questions dealing strictly with improvement in hearing ability were given scores of 5. Taken together with the results of the speech intelligibility study, these findings demonstrate both the need for and acceptability of the IR hearing aid.

APPLICATIONS OF IR TRANSMISSION OF SOUND

Entertainment Devices

Transmission of sound with IR light also has application to a variety of acoustical communication situations. IR light transmission of TV audio and high fidelity sound has already been introduced to the commercial home entertainment market by Sennheiser Corp. but does not appear to have found wide acceptance. Sennheiser's system is beyond the financial reach of most people, retailing for about $300. In addition, the device is limited to TV sets equipped with an earphone plug, and unfortunately the great majority of TV sets sold here are not so equipped.

Public Address Systems

IR transmission of sound has obvious application to public address systems in theatres, churches, classrooms, lecture halls and other large enclosures, where even normal listeners often have difficulty understanding audio messages. It is well-known that many hearing-impaired persons are almost totally incapacitated under such conditions, and often avoid taking part in activities in these settings. It is not uncommon, for example, to find partially hearing individuals who never go to the theatre, attend lectures, or even watch TV, simply because they cannot understand what is being said. Moreover, it is not uncommon to find such individuals incorrectly labelled as "cognitively deficient".

Auditory Trainers

Nowhere is the problem of auditory communication more crucial than in educational settings. Now that "mainstreaming" of handicapped children in the neighborhood school has been mandated by federal law, the hard-of-hearing child is placed to an increasing degree in the normal classroom. Consider the typical classroom situation where a partially hearing child must understand the instructions of a teacher presented under the ordinary commotion of the classroom. The typical hearing aid, as pointed out earlier, may be of little help in this noisy situation. How much of an improvement would be realized —for child and teacher alike—from an IR system in the classroom is difficult to estimate. The opportunity for a severely hard-of-hearing young child to have good sound at a very early age, both at home and at school, might well make the difference between a permanent speech disorder and substantially normal speech.

Auditory trainers have long been used to bring sound, via induction loop or radio broadcasts, directly to students in schools for the hard-of-hearing. To the best of our knowledge, this approach has not been made available outside of schools for the deaf.

CONCLUDING REMARKS

The overall aim of our research program is to develop, evaluate and clinically test an infrared light transmission hearing aid. Thus far, the major effort has been directed at elucidating the auditory profile of potential candidates for the infrared hearing aid. In this effort we have introduced a new measure of speech performance in noise, for application in audiometric evaluations of hearing loss and as a predictor of acceptance of IR hearing aids.

In conjunction with the clinical investigations, a laboratory prototype IR device has been shown, in preliminary laboratory tests, to be far superior to the conventional hearing aid under many simulated everyday conditions. By conducting clinical investigations together with the engineering development at the same facility, we have been able to insure a close collaboration between personnel from the two related projects.

REFERENCES

Anianson, G.: Methods for Assessing High Frequency Hearing Loss in Everyday Listening Situations. Acta Otolaryng. Suppl. 314, 1974.

Carhart, Raymond, and Thomas Tilman: Interaction of Competing Speech Signals with Hearing Losses. Arch. Otolaryng. 91(3), 273–279, Mar. 1970.

Courtois, J.: Binaural IROS Fitting of Hearing Aids, Scand. Audio. Suppl. 5:194-230, 1975.

Federal Trade Commission. Report of the Presiding Officer on Proposed Trade Regulation Rule for the Hearing Aid Industry. Aug. 1, 1977, Washington, D.C.

Gardner, M.D.: Factors Affecting Individual and Group Levels in Verbal Communication. J. Audio. Engng. Soc. 19:560–569, 1971.

Kruel, James, Jamas Nixon, Karl Kryter, et al.: A Proposed Clinical Test of Speech Discrimination. J. Speech Hearing Res., 11(4):536–552, 1968.

Leshowitz, Barry: Applications of Psychoacoustics to Clinical Audiology. Netherland Society of Audiology, Amsterdam, Jan. 1977, Summary *in* Audiology, 17:90–91, 1978.

Leshowitz, Barry: Speech Intelligibility in Noise for Listeners with Sensorineural Hearing Damage. Institute for Perception Research (IPO), Annual Progress Report. (A. J. Breimer, ed.), Eindhoven, the Netherlands, 1–12, 1977.

Leshowitz, Barry and Robert Lindstrom: Masking and Speech-to-Noise Ratio. Proceedings of the Workshop on Prosthetics and Technical Devices for the Deaf, (D.O. McPherson, ed.), National Technical Institute for Deaf, Rochester, N.Y., 1978. (In press)

Miller, James D. and Arthur F. Niemoeller: Hearing Aid Design and Evaluation for a Patient with a Severe Discrimination Loss of Speech. J. Speech and Hearing Res., 10:367–372, 1966.

Plomp, Reinier: Auditory Handicap of Hearing Impairment and the Limited Benefit of Hearing Aid. J. Acoust. Soc. of Amer., 63:(2), 533–549, Feb. 1978.

Skinner, Margaret W.: Speech Intelligibility in Noise-Induced Hearing Loss: Effects of High-Frequency Compensation. Ph. D. Dissertation, 180 pages, Washington University, St. Louis, Mo., 1976.

Suter, A.H.: The Ability of Mildly Hearing-Impaired Individuals to Discriminate Speech in Noise. Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. 1978.

Wilder, Charles S.: National Health Survey. Prevalence of Selected Impairments, United States, 1971. Nat. Cent. for Health Statistics, Vital and Health Statist, Data from NHS: Series 10-No. 99, DHEW Publ. No. (HRA) 75-1526, Rockville, M.D., 1975.