THE EFFECT OF DIFFERENT POSITIONS OF THE REFERENCE MICROPHONE ON THE SPL IN PROBE TUBE MEASUREMENTS

Reg. No. M 9823

AN INDEPENDENT PROJECT SUBMITTED AS PART FULFILMENT OF THE FIRST YEAR M.Sc (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE.

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MYSORE - 570 006

MAY 1999

DEDICATION

My sincere dedication to ***Dad and Mom,***
who have moulded me to what I am today.

Certificate

This is to certify that the independent project titled **"The effect of different positions of the reference microphone on the SPL in probe tube measurements"** *is a bonafide work in part fulfilment of the First year M.Sc, in speech and Hearing of the student with* ***Reg. No. M 9823.***

Mysore
May 1999

Director,
All India Institute of
Speech and Hearing,
Mysore

Certificate

This is to certify that the Independent project entitled **"The effect of different positions of reference microphone on the SPL in probe tube measurements"** *has been prepared under my supervision and guidance.*

Mysore
May 1999

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Lecturer in Audiology
All India Institute of
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Mysore

DECLARATION

I hereby declare that this independent project entitled **"The effect of different positions of the reference microphone on the SPL in probe tube measurements"** is the result of my own study under the guidance of **Dr. K. Rajalakshmi,** Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier to any university for any other Diploma or Degree.

Mysore

May 1999 Reg No. M 9823

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God had been so magnanimous to gift me with such wonderful parents, Thank you so much for all your patience and guidance.

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INTRODUCTION

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One of the most wonderful gifts that has been bestowed upon man would be the gift of hearing. The hearing system of man is very sensitive to speech which differentiate man from other human beings.

We can say that hearing is essential for the acquisition of speech and language. It also enables individuals to localise and discriminate different sound sources in the environment. Hence, impairment in hearing renders a person unable to appreciate the different sounds in the environment and more important is the inability to understand and produce speech.

There are various definitions for hearing loss. The most simplest one is "A decrease in the sensitivity of hearing" (Sanders, 1971). The problem of hearing loss can be solved by means of amplification. It is the single most important rehabilitative tool available to the hearing impaired population (Ross, 1975; Ross and Giolas, 1978; Bess and Me Connell, 1981).

Hearing aids are the most commonly used amplification devices.

The challenge of developing scientifically based methods of selecting, evaluating and fitting hearing aids moved a giant leap forward with the advent of computerised probe microphone real ear technology. Successful clinical applications were dependent on the culmination of a number of technological innovations achieved during the 1980's.

It has always been clear that the optimal measurement of hearing aid performance should somehow be taken near the tympanic membrane while the amplification system is being worn and used by a human subject. **Unoccluded probe microphone measurements along the external ear canal were reported as early as 1946 by Weiner and Ross.**

Probe microphone measurements of hearing aid amplification has been available since then. Harford and his colleagues continued to develop and describe the clinical application of this real-ear in situ measurement technique (Harford, 1980a, 1980b, 1984; Harford, Leijon, Liden, et al. 1983; Wetzell and Harford, 193). Dalsgaard and Dyrlund Jensen (1976) compared real-ear probe-microphone measurements in unoccluded and occluded ear canal conditions with the ear mold and hearing aid in place.

Acoustic measurements performed in the ear canal, with and without ear mold and hearing aid in place, provide valuable information regarding the total combination of influences on the amplification device, including the impedance characteristics of the ear anatomy itself, as well as the acoustic plumbing (the tubing and ear mold attached to the hearing aid) and natural resonance of the individual's ear (Libby and Westermann, 1988).

Dedicated computer probe-microphone systems are designed specifically for real-ear measurements only. It consists of a miniaturized, very soft silicone probe-tube extension for making measurements near the tympanic membrane. The electret reference microphone maintains the stimulus level near the patient's ear at a constant sound pressure level (SPL) during the test signal presentation. **The main purpose of the reference microphone is to act as a standard against which the probe signal is compared.** The reference microphone eliminates most of the influence created by patient movement and poor environmental acoustic conditions. It also eliminates the need for testing to be conducted in a sound-treated test booth or room.

Most real ear measurement systems locate the reference microphone somewhere near the test ear pinna, although if the reference microphone is located too near the microphone of the hearing aid under evaluation, feedback conditions may exist when sufficient hearing aid gain is determined.

Variables like position of the loudspeaker at a 0° or 45° or 90° azimuth, instruction to the patient to not to move his head, use of modified pressure method of sound field equalization, insertion depth of the probe tube i.e. 25-30 mm past the tragus and maintaining the same position for all measurements, use of a broad-band signal for all Real Ear Aided and Real Ear Insertion Gain measurements are some of the conditions to be considered to get reliable and valid results.

The present study aims to study the effect of external reference microphone placement upon the absolute value and variability of measured SPL, at six external locations (i.e) 2 cm, 4cm and 6 cm in the forward and rear positions.

The following were the aims of the study:

a) To investigate the relationship between output SPL and the position of reference microphone placement as the distance of the reference microphone placement was changed from 2 cm to 6 cm in the forward and rear positions.

b) Whether there was a significant difference within front positions at 2 cm, 4 cm and 6 cm reference microphone placement and

c) Whether there were significant differences within 2 cm, 4 cm and 6 cm of the reference microphone placements in rear position.

d) Whether there was significant difference between the different reference microphone placements in the front and rear positions.

HYPOTHESIS:

To study the effect of various reference microphone placements on Output SPL following hypothesis were made:

a) There is no relationship between output SPL and the position of reference microphone placement as the distance of the reference microphone placement is changed from 2 cm to 6 cm in the front and rear positions.

b) There is no significant difference within front positions at 2 cm, 4 cm and 6 cm reference microphone placements and

c) There is no significant difference within 2 cm, 4 cm and 6 cm of the reference microphone placements in rear position.

d) There is no significant difference between the different reference microphone placements in the forward and rear positions.

REVIEW OF LITERATURE

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In 1983, a highly sophisticated, Apple computer-based probe-microphone system, which featured a self-calibrating microphone and soft silicone tube that could be placed under the earmold of the hearing aid into the patient's earcanal was introduced in Europe by Steen B. Rasmussen and H. Birk Nielsen(1984). This instrument was designed to be clinically easy to use and did not require a typical sound treated booth to reduce environmental noise (Northern, J.L., 1982).

This instrument offers objective measurement of hearing aid performance from within the earcanal and such measurements verified the performance characteristics of the hearing aid and also the interaction of amplification and impedance of the auricle, earcanal, and tympanic membrane. For the first time, **audiologists could easily measure the natural resonance of the unoccluded ear canal, which could then be included into the fitting rationale used to select an appropriate hearing aid.** A large part of the appeal of PTM (Probetube Measurement) has been that they are "objective" measures of real ear hearing aid performance. There are, however, many potential sources of variability in these measurements (Northern, J.L., 1982).

Revit (1987) identified the following 22 sources of variability mentioned in the literature and discovered in his study:

- Movement of probe microphone between aided and measurements.
- Changes in position of probe microphone across measurement pairs.
- Movement of subject's head between aided and unaided measurements.
- Change in position of subjects head across measurement pairs.
- Selected standard measurement location in the ear canal.
- Errors caused by the acoustics of different rooms (Ringdahl and Leijon, 1984).
- Change in placement of the hearing aid across measurements.
- Difference in input level to the hearing aid (Hawkins and Mueller, 1986).
- Carelessness by clinician.
- Improper sealing of the earmold (Hawkins, 1987a).
- Leaks between the earmold and probetube (Tecca, Woodford and Kee, 1987).
- Deformation of the probe tube.
- Equipment noise (Dillon and Murray, 1987).
- Room noise.
- Diffraction effects of head ornaments, jewelry, and measuring apparatus.
- Change of insertion depth of the earmold.

- Change in density and arrangement of head hair in the vicinity of ear.
- Change in loudspeaker placement.
- Change in hearing aid output characteristics.
- Change in selected head and body position (posture).
- Effect of cerumen (change in earcanal impedance or blockage of the probetube).
- Noises made by the subject (Internal or External)

Some probe tube microphone systems use a pressure type sound field equalization for the reference microphone location near the auricle lobule- a significant distance away from the hearing aid microphone inlet. The five methods used for sound field equalization are pressure method, Comparison method, modified comparison method, substitution method and equivalent substitution method.

These methods were initially developed with the sinusoidal signals as the acoustic input of choice to be presented in an essentially reverberation and noise free environment.

Real ear measurements are rarely made in an anechoic environment and are often carried out in an acoustically untreated with significant levels of reveberation and environmental noise (Davis A. Preves and Roy F. Sullivanng the, 1987).

Among the five methods available for sound field equalization, the pressure and comparison methods perform an instant-by-instant correction of sound field levels across the frequency range of interest at the position of the reference microphone. The pressure and comparison methods utilize two microphones which are concurrently active-one for reference and one for probe measurement of the hearing aid response. A number of manufacturers of probe microphone systems purpose to use the "pressure" method or" comparison" method of sound field equalization. The reference microphone is located inferior to the earlobe. Other reference positions studied include the tip of the nose, the cheek and the vertex (Davis A. Preves and Roy F. Sullivan, 1987).

As these reference microphones are placed comparatively far away from the microphone port of the hearing aid, these systems are not performing the pressure method of equalization as described in the IEC and ANSI standards.

Rather they are actually performing a modified comparison method of equalization because the reference and hearing aid microphones are located at two different and acoustically dissimilar points in the sound field. This type of reference measurement is called **modified comparison method.** This method can be used for insertion gain measurements (Davis A. Preves and Roy F. Sullivan, 1987).

STORED METHODS

In order to accomplish a stored sound field equalization, probe tube microphone systems may utilize one or two microphones. Stored sound field equalization is performed as a separate step prior to the actual measurements. The probe tube microphone system microcomputer stores the required equalization values to produce a spectrally flat (or a controlled shape) stimulus at the test point. When separate reference and measurement microphones are used, the reference microphone is turned off after equalization during the measurements.

The advantage of stored equalization methods is the ability to regulate the sound field independent of SPL produced by resonance of the unaided ear or acoustical leakage emanating from the ear. During actual measurements, the reference microphone is inactive. Hence the reference microphone during the measurements will not sense any changes in sound field (Davis A. Preves, 1987).

In 1980, Harford published some of the first clinical "real ear" measures, using different reference sites including placement within the contralateral ear canal and at the ipsilateral superior rim of the pinna (Harford, 1980-1982; Kuhn and Burnett, 1977). There are problems with the use of the contralateral ear, later recognized by Harford, (1982), including.the assumption that both external ears are equivalent in their respective geometries. In addition, contralateral canal placement does not take into account canal and pinna resonance. The helix and pinna placements have not been systematically investigated in terms of their reliability.

If absolute measures of SPL in the ear canal are being made, substantial differences can be observed depending on the location of the regulating microphone.

Ickes et al(1991) did a study by examining the effect of three loudspeaker locations (0°, 45° and 90°) and three reference - microphone locations (over the ear, on the check and at the ear) on the Real Ear Unaided Response, Real Ear Aided Response and Real Ear Insertion Response of both In The Ear (ITE) and BTE (Behind The Ear) hearing aids. A Frye 6500 probe microphone system was used with a KEMAR(Knowles Electronics Manikin for Acoustical Research). All sizeable differences that resulted from reference microphone location and loudspeaker azimuth were restricted to frequencies above 2000Hz. The largest variations are seen at the 90° loudspeaker azimuth and with the at-the-ear regulating microphone location. The results of this study would suggest that a 0° or 45° loudspeaker azimuth with either an over-the-ear or cheek regulating - microphone location is the preferable measurement condition.

The present study reports of the effect of external reference microphone placement upon the absolute value and the variability of measured SPL at six different external locations (i.e.) 2 cm, 4 cm and 6 cm in the front and rear directions respectively.

METHODOLOGY

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A) SUBJECTS: 10 Subjects including 5 males and 5 females of age ranging from 19 to 23 years were selected for study. Either right or left ear was tested and these subjects fulfilled the following criteria:

i) Pure tone audiometry results revealed that all the subjects had hearing within normal limits.

ii) Immitance audiometry revealed no middle ear pathology

iii) All the subjects underwent an ENT check up to rule out the presence of any external or middle ear problems.

B) INSTRUMENTATION: The FONIX 6500-C, hearing aid test system was used to perform the real ear measurements. The instrument was calibrated as per instructions given in the Operations Manual.

C) TEST ENVIRONMENT: Probetube measurements were carried out in sound treated room where the ambient noise level was within permissible limits (IS [1991] standard).

D) TEST SIGNAL: A composite tone signal was presented through a loud speaker at an intensity of 70 dB SPL.

E) TEST PROCEDURE:

PRE MEASUREMENTS PROCEDURE: The leveling of the instrument FONIX 6500C was carried out prior to the measurements. The subject was seated 12 inches from the loud speaker. The loud speaker was placed at a 45° azimuth relative to the patient's seating. The head band was secured above the ears and ear hanger was placed around the ear to be tested. The reference microphone was placed firmly over the headband. The 6 locations of reference microphone are 2 cm, 4cm and 6 cni in front of pinna from the helix and 2cm, 4cm and 6cm in the rear position, at the back of the pinna in the plane of the tip of helix.

The probe tube was placed in the ear of the subject such that it extended 5 mm beyond the canal portion with a marker pen. The patient was instructed to look straight and not to move or talk until the test was complete. Initially the Real Ear Unaided Response (REUR) was measured. This response gave the information regarding the ear canal resonance.

Following precautions were taken while carrying out the probe tube measurements.

i) Care was taken to exclude the reflecting surface in testing condition.

ii) The subjects were instructed to keep the head straight as head movements on the part of the patient would affect the measurements.

iii) A constant insertion depth of the probe tube was maintained.

iv) Care was taken to ensure that the loudspeaker azimuth was always maintained at 45°

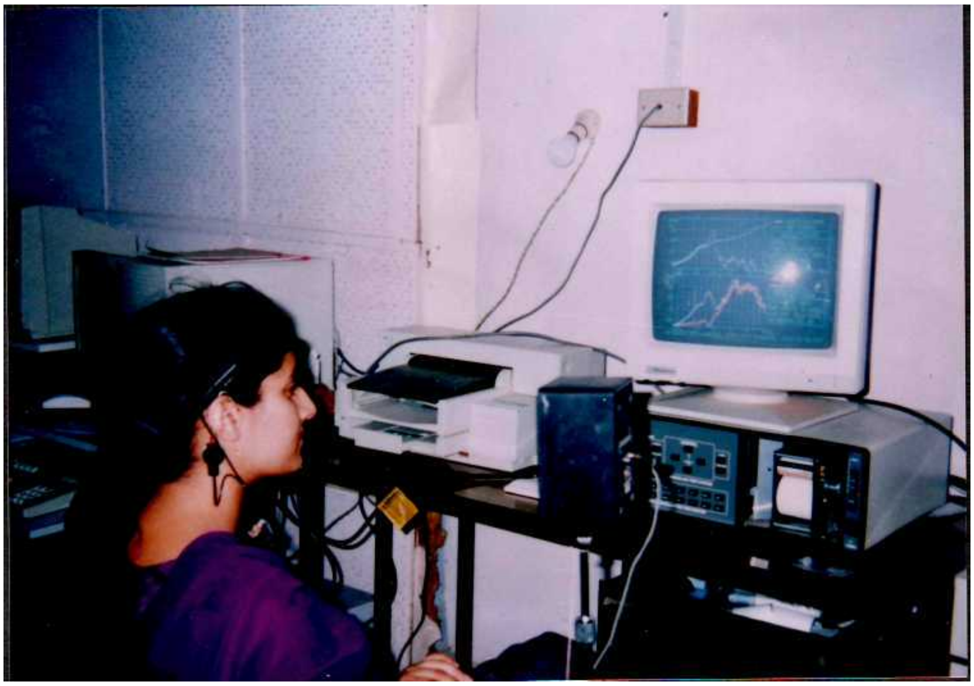
v) During the Real Ear Unaided Response measurements, negative values were obtained whenever the probetube was crimped or the tip was directly against the wall of the canal. Reinsertion or removal of the crimp was done to solve the problem. The placement of the reference microphone at 2cm, 4cm and 6cm in front and rear positions was monitored using a predetermined scale which helped in placing the reference microphone at appropriate positions.

The output SPL at different positions of the reference microphone and the gain for frequencies ranging from 200Hz to 8000Hz was obtained on the screen by pressing a data button and the values were noted down. The mean of the gain from 2000Hz to 4000Hz was calculated.

RESULTS & DISCUSSIONS

IGO - HAT (Insertion Gain Optimiser - Hearing Aid Trial)

Fonix 6500C



This is the instrument used for probe tube measurements at the Department of Audiology, All India Institute of Speech and Hearing, Mysore.

RESULTS AND DISCUSSIONS

The main purpose of this study was to find out the effect of the probe tube reference microphone placement on sound pressure level variability, within and between different positions in front and rear positions. The results were subjected to analysis.

a) To investigate the relationship between output SPL and the reference microphone as the distance of placement was changed from 2 cm to 6 cm in the front and back positions.

b) Whether there were significant differences within front positions at 2 cm, 4 cm and 6 cm reference microphone placements and

c) Whether there were significant differences within 2 cm, 4 cm and 6 cm of the reference microphone placements in rear positions.

TABLE. A MEAN AND STANDARD DEVIATION & RANGE OF THE GAIN FOR DIFFERENT PLACEMENTS OF REFERENCE MICROPHONE (for frequencies 2-4 KHz)

SPL FORWARD	MICROPHONE PLACEMNT		
	2cm	4cm	6cm
MEAN	19.83	20.30	20.04
SD	3.5	4.63	3.51
RANGE	13.68-24.97	14.5-28.59	13.5-25.16
REAR			
MEAN	18.8	19.94	18.58
SD	3.25	2.51	3.48
RANGE	14.88-24.71	16-24	13.19-24

TABLE. B SIGNIFICANCE OF DIFFERENCE BETWEEN AND WITHIN MEANS OF DIFFERENT PLACEMENTS IN THE FRONT AND CORRESPONDING REAR POSITION OF THE REFERENCE MICROPHONE

't' SCORES

SPL	2cm	4cm	6cm
BETWEEN FRONT AND REAR	3.85	3.58	2.78
WITHIN FRONT	2cm & 4cm	4cm & 6cm	6cm & 2cm
	3.195	3.29	2.85
WITHIN REAR	3.41	3.35	2.73

Significant at 0.05 and at 0.01 levels.

't' test was done & the analysis of t-scores indicated that:

a) There was significant difference in the dB SPL values between the front and rear position of the reference microphone at 2cm, 4cm & 6cm placements.

b) There was significant difference in the dB SPL values within the three placements of the reference microphone (2,4 & 6 cms) in the front positions and correspondingly in the rear positions.

Thus, from the above study, the following conclusions were drawn:

a) As the distance increases, the output SPL decreases (i.e.)as the reference microphone is moved away from the ear - 2cm to 6cm, the output SPL of the earcanal decreases. Hence an ideal position would be to place the. reference microphone at 2 cm in front.

b) When compared to the output SPL in the front position and rear position, the front position appears to give more gain than the rear position.

c) When we compare the different placements with respect to distance 2cm appears to give more gain than 4cm & 6cm, both in the front and rear positions.

The results obtained in the study are in agreement with the results of Lawrence I. Shortland and Kurt study(1990). They reported that rear microphone placement produced lower dB values, while positions in the front produced the largest. According to them, for clinical use, the differences may be trivial, while from a laboratory point of view, they may be significant with respect to variance. They also found that variability within an individual changes as the microphone is moved between positions.

SUMMARY & CONCLUSIONS

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"A decrease in the sensitivity of hearing" is the simplest definition of hearing loss (Sanders, 1971) and this can be rectified by amplification. Hearing aids are the most commonly used amplification devices. Selection, evaluation and fitting of hearing aids moved a giant leap forward with the advent of computerised probe microphone real ear technology. Real Ear Unaided Response and Real Ear Aided Response are recorded and this varies from individual to individual.

The electret reference microphone maintains the stimulus level near the patients ear at a constant sound pressure level (SPL) during signal presentation. Many variables are to be considered to get reliable and valid results.

Hence the aim of the study was to study the effect of reference microphone placement upon the measured SPL at six external locations - 2cm, -4cm & 6cm in the front and rear positions.

The reference microphone was placed firmly over the headband of the subjects head and the Real ear Unaided Response was obtained for 6 different locations of the reference microphone. The other variables such as loudspeaker placement of 45° azimuth, depth of the probe tube etc were all maintained constant. The instrument used was FONIX 6500C and SPL readings were recorded across a frequency range of 200-8000Hz. The experiment was carried out on 10 normal hearing subjects in a quite room wherein the ambient noise levels were within the permissible limits (IS [1991] standard).

Statistical analysis revealed significant difference in the output SPL between and within the front and rear positions of the reference microphone at 2cm, 4cm and 6cm placements. Furthermore, it was also found out that as the distance increased from 2cm to 6cm, the output SPL decreased both in front and rear positions. Again, in the front, the output SPL was more when compared to the rear positions of the reference microphone.

The results of the present study are in accordance with another study bv Lawrence I Shortland and Kurt (1990) which examined the effect of external microphone reference placement or peak SPL and measurement variability. The highest peak SPL values were recorded lateral to the pinna and a reference site 2cm from the pinna eliminates attenuation of the signal and is the least variable site.

From the present study, it can be concluded that the front position at 2cm is the least variable site of the reference microphone that gives maximum output SPL and forward placement gives more output SPL than rear placement. Hence it can be concluded that the placement of the reference microphone can affect the accuracy of ear canal measurements.

SUGGESTIONS:

Ear canal resonance plays a very important role in probe tube measurements. As it is a **variable across different age groups and clinical population** like surgically operated earcanal or congenital anomalies of the external ear, similar studies can be taken up in future to get more interesting results.

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