# *INSERTION GAIN MEASUREMENT FOR HEARING AID SELECTION - AN AUDIO VISUAL SCRIPT.*

**Reg. No. M 9201**

*An Independent Project submitted in part fulfilment for the First Year M.So. (Speech and Hearing) University of Mysore. Mysore.*

All India Institute of Speech and Hearing,
Mysore - 570 006.
1993

Dedicated to

Ajja and Ajji.

## CERTIFICATE

This is to certify that the Independent Project entitled : Insertion Gain Measurement for Hearing Aid Selection - An Audio Visual Script, is the bonafide. work in part fulfilment for M.Sc., in Speech and Hearing, of the student with Reg. No. M 9201.

Director

*Mysore*
*1993*

*All IndiaInstitute.*
*of Speech and Hearing*
*Mysore-* 5 70 *006*

# CERTIFICATE

This is to certify that the Independent Project entitled : Insertion Gain Measurement for Hearing Aid Selection - An Audio Visual Script, has been prepared under my supervision and guidance.

Dr. (Ms.) S.Nikam,
Prof..&Head
Audiology Dept.
GUIDE

Mysore
1993

## DECLARATION

This Independent Project entitled : Insertion Gain Measurement for Hearing Aid Selection - An Audio Visual Script, is the result of my own effort under the guidance of Dr. (Ms.) S. Nikam, Prof and Head of the Dept. of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore
1 993

Reg. No. M 9201

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I extend my sincere thanks to Mrs. Rajalakshmi, for having helped me patiently from the start till the end of this project.

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# GENERAL INTRODUCTION

When a hearing impaired individual approaches an audiologist, the foremost task of the audiologist is to assess and evaluate the hearing acuity of the individual. But is it all that an audiologist does? The answer to this query is obviously, a "No".

The audiologist also lays his hands in rehabilitating the hearing impaired individual. A 'suitable' amplification device, most often a hearing aid is given. Now what does the term suitable amplification device imply?

All hearing aids do not fit all individuals and neither do all of them provide adequate amplification. Hence, we've to perform a detailed hearing aid evaluation for each individual, search for the appropriate hearing aid that would best suit the individual's needs of hearing both at and outside home.

However, a major question that arises is how do we evaluate and select a hearing aid for an individual?'. This, of course is not an easy procedure. It involves lot of patience and skill on the part of the clinician. A number of different commercial hearing aids can be prescribed to the hearing impaired individual with acceptable sound quality, good speech intelligibility and maximum sound output which

is not too loud. The clinician preselects one or many hearing aids for each individual. This is necessary for an appropriate and accurate hearing aid evaluation.

Two predominant approaches, to hearing aid selections have come into picture. The comparitive and the prescriptive procedures.

The comparitive procedure compares hearing aids with each other as the basis of selection. The presricptive procedure focusses on the determination of appropriate electro - accoustic characteristics for a hearing aid and frequency gain function which is necessary for an individual.

This project deals with the prescriptive procedure and various steps involved before and during the administration of insertion gain measurements in detail.

## Audio Visual Script for Insertion Gain Measurements:

## INSERTION GAIN MEASUREMENTS: INTRODUCTION

| Visual | Audio |
| --- | --- |
| Different types and Categories of hearing aids can be highlighted. | With modernization of hearing aid technology, many manufacturers have taken up production of different types and categories of hearing aids. These hearing aids do not vary much from each other. Yet the clinician faces a lot of problems while making a selection of hearing aid which best meets the persons needs.<br><br>For the last decade, hearing health professionals silently have been questioning the validity, repeatability and subjectivity of the standard methods of hearing aid evaluation and fitting procedures. It is almost superfluous to |

**Visual** **Audio**

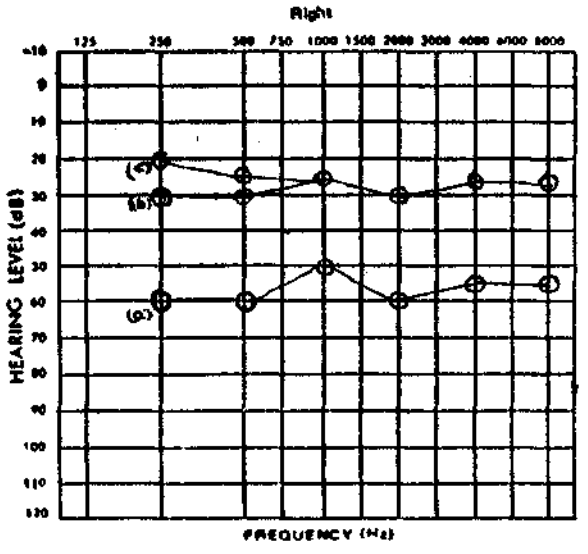
note that despite valiant efforts to develop a scientifically based approach to hearing aid selection, very little progress has been made over the past 50 years. Hearing aid trial methodology lacks standardisation and its selection is frequently based on the personal preference of the dispenser.

Administration of real ear measurement on a patient can be focussed.

The advent of practical real-ear measurement systems offers an objective means of quantifying, describing and evaluating the sound received at the level of the eardrum. The effect of critical variables produced by acoustic modifications (venting, filters, horns), directional microphones & CROS fittings now can be measured objectively and with a high degree of

repeatability. Real ear measurement allow dispenser to visualize what the hearing aid user is experiencing, thus allowing her / him to proceed with a higher degree of confidence.

Graphical Representation of the hearing aid gain according to half gain rule and POGO I are shown below.




(a) THRESHOLD OF HEARING

(b) GAIN OF THE HEARING AID TO BE PRESCRIBED. (ACCORDING TO HALF GAIN RULE).

(c) GAIN OF THE HEARING AID TO BE PRESCRIBED (ACCORDING TO POGO I FORMULA).

Hitherto there is no universally accepted hearing aid selection procedures, Many investigators have put forth different prescriptive and comparative procedure for the selection of hearing aids. A few of the prescriptive procedures are

1) Lybarger's half gain rule.

2) Mc Candless & Lyregaard gave POGO I & II formulae.

3) NAL etal.

In this procedure combination of both half gain rule &. l/3rd gain rule is used.

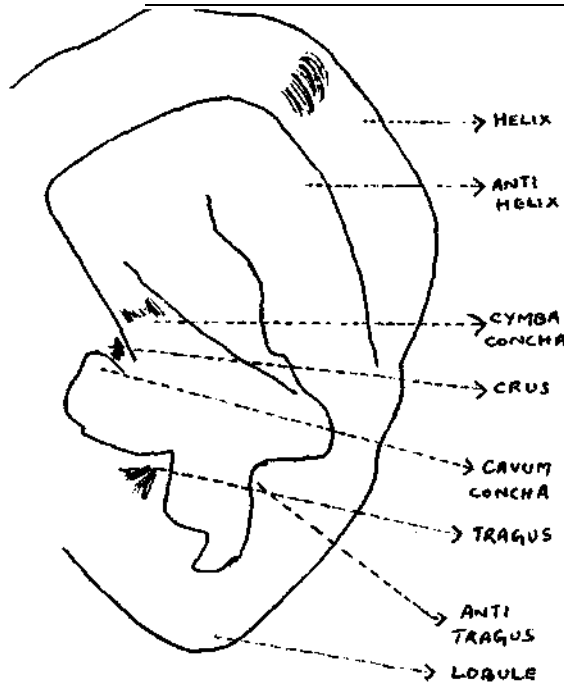
**Visual** **Audio**

4) Berger's formulae (1984). Carhart's speech tracking, speech intelligibility tracking are some of the comparitive procedures.

Parallel with the development of hearing aids and selection techniques there is an improvement in electro-acoustic evaluation techniques of hearing aids. From basic coupler measurements, the technology has advanced to more sophisticated real ear or insertion gain measurements with computerized techniques.

## EXTERNAL EAR; A BRIEF VIEW

THIS DIAGRAM REPRESENTS PINNA AND ITS COMPONENTS




To understand the real ear measurements a knowledge of anatomy and the resonance characteristics of the external ear becomes essent ial.

The external ear is composed of the pinna and the external auditory meatus. Auricle is a flap like catilagenous structure which is externally visible and attached to the sides of the head at an angle of 30. It is a sound collector that is it is through the auricle that the sound vibrations in the air are picked up, directed and conveyed through the external meatus to strike the typmanic membranes. It also guards deeper parts of auditory apparatus. The surface of

**Visual** **Audio**

the auricle is formed of many elevations and depressions.

Concha is the deepest depression and lies somewhat in the centre of the auricle. It is surrounded by a less elevated area cal1ed scapha.

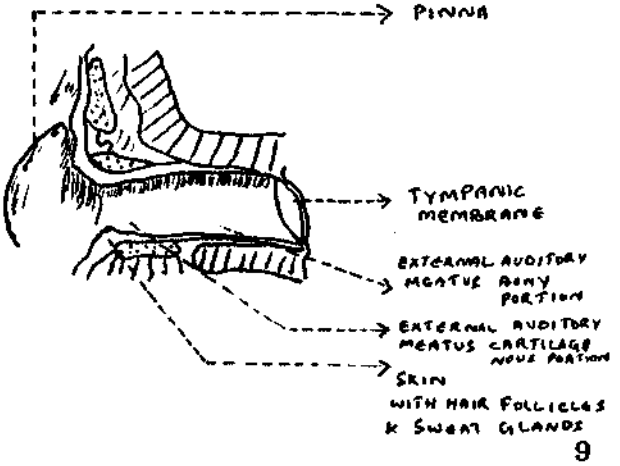
Helix is the curved rim of the entire auricle. On the posterior portion of the helix a small thickening, the Darwin's tubercle is present. Parallel to the helix is a semicircular ridge called anti-helix.

Tragus is the small ridge 1 ike boundary for the concha anteriorly. Just opposite the tragus is the anti-tragus. These two are separated from each other by intra-tragal incisura.

Lobule is the inferior most part of the auricle which is soft.

Localisation of the sounds with respect to space is based upon the intensity of stimulus and phase of sound waves coming from a single source and received by the two ears. The sounds are also diffracted around the corner and there is a partial loss of energy and reduced intensity accomplished by a lag of time arrival into the ear.

THIS DIAGRAM REPRESENTS EXTERNAL AUDITORY MEATUS




External auditory meatus is a tube like passage through which the sound waves traverse to reach the eardrum or the tympanic membrane.

This passage is approximately one inch or 25mm long and l/4th of an

inch or 6-7mm wide. The external l/3rd of the meatus has carilagenous support whereas internal 2/3rd is formed by bony support.

The ear canal acts as a sound pressure detector. It also acts as a tube open at one end and closed at the other thus creating resonances at different frequencies. On the whole, the function of this is efficient transmission of the sound from the environment to the eardrum.

External ear has other non-auditory functions also. The auricle and the auditory canal are protective in nature because of their anatomical shape. They prevent direct injury to the eardrum and to the other underlying structures.

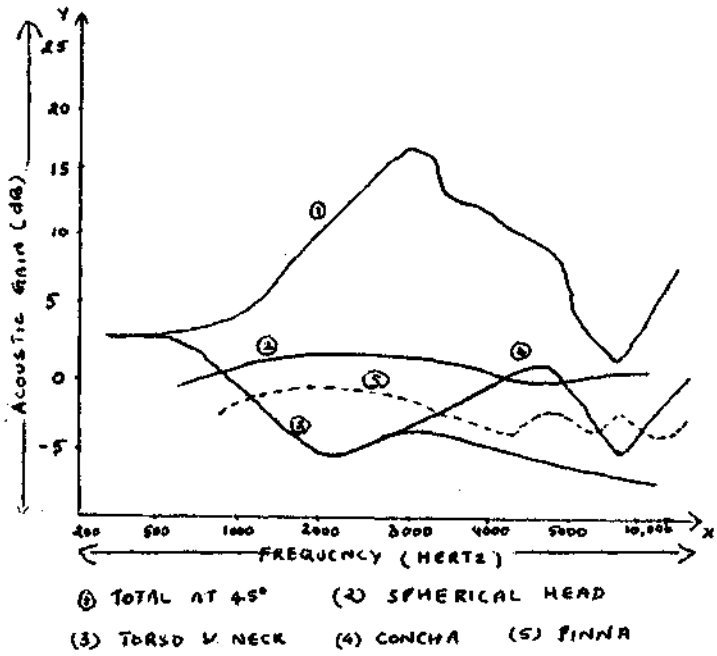
**Visual Audio**

The earcanal has ceruminous glands which secretes wax. In addition it has hairs. Both these assist in preventing any foreign body from entering the canal.

EXTERNAL EAR EFFECTS: UNOCCLUDED AND OCCLUDED EARS

**Visual**

CONTRIBUTION OF DIFFERENT ANATOMICAL STRUCTURE TO THE SOUND PRESSURE GAIN




**Audio**

The primary resonance of the external ear occurs at 2.7 KHz. The angle of incidence has an effect, maximum being at 45 azimuth.

For insertion gain measurements sound pressure has to be transfered from free field to the human ear drum. In the freefield, before the sound reaches the eardrum, sound waves are influenzed by the head and

torso. These influences come into picture when insertion gain measurements are carried out and not so when the couples measurements are done.

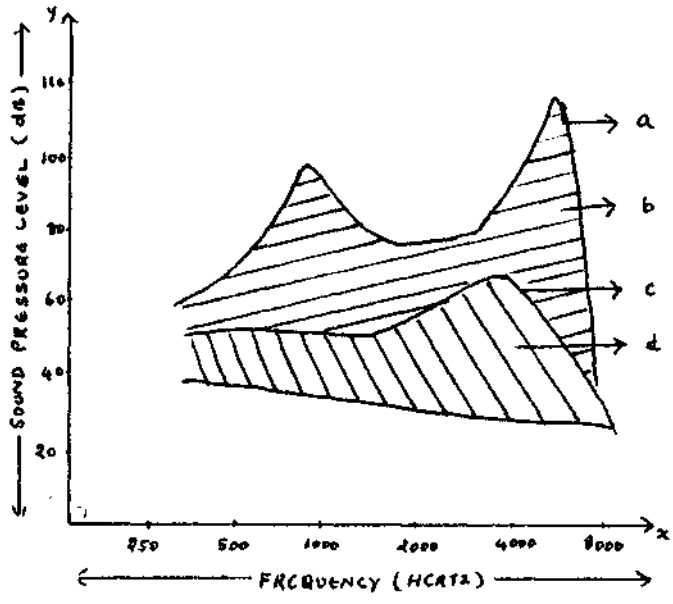
Gain offered by different parts of the external ear is represented in this table.

| PART OF EXTERNAL EAR | GAIN | LOSS |
|---|---|---|
| PINNA<br><br>CONCHA<br><br>EXTERNAL AUDITORY MEATUS | 3dB at 4kHz<br>l0dB At 4-5KHz<br>17dB At 2.7KHz | 5dB at 10 KHz |

| PART OF EXTERNAL EAR | GAIN | LOSS |
|---|---|---|
| PINNA<br><br>CONCHA<br><br>EXTERNAL AUDITORY MEATUS | 3dB at 4khz<br>l0dB At 4-5KHZ<br>17dB At 2.7KHz | 5dB at 10 KHz |

**Visual Audio**

EAR CANAL RESPONSE IN THE OCCLUDED AND UNOCCLUDED CONDITIONS




**[a) OCCLUDED EAR CANAL RESPONSE**

**(b) INSERTION GAIN**

**(c) Unoccluded EAR CANAL RESPONSE**

**(d) OPEN EAR RESPONSE.**

When concha, ear canal and typmpanic membrane complement each other, they broaden the gain between 2-5kHz, which is important for speech perception. In total there is a broadened maximum between 2-5 kHz.

Bilateral representation of the ears and the presence of elevations and depressions in the ear help to improve the natural directionali1ty of human acoustic antenna system. But in patients with deviations in hearing sensitivity the human acoustic antenna system is affected along with the disturbances in speech preception. For such cases suitable amplification devices, usually hearing aid is prescribed. Even with this, there will be a

problem when complex signals such as speech has to be understood, more so when there is noise in the environment. The main aim of amplification content which could be achieved by adjusting the frequency response and other such parameters of the hearing aid. This is accomplished by the use of Insertion Gain Optimization.

## HISTORICAL PERSPECTIVE OF INSERTION GAIN OPTIMIZATION

### Visual

Chart representing different stages of insertion gain measurements:

- Zwisloccki Coupler (1940)
- KEMAR (1972)
- Real ear measurement technique (1980)

### Audio

Now let us gain an insight to the historical perspective of Insertion Gain Optimization.

The idea of insertion gain measurements using the probe microphone is not new. It's developmental history

**Visual**

**Audio**

can be traced back to as early as 1940's. But its clinical use gained significance in late 1980's, nearly half a century after its inception by Romanow (1942) who stated that 2cc coupler was not a real ear simulator, but is very convenient for calibration and quality control measures.

The use of real ear measurement is a gradual development from the use of 2cc coupler. The developmental stages were zwislocki coupler. KEMAR (1972) and then the real ear measurement technique.

The increased use of earmold acoustic systems has changed trends to making requirements on actual ear canal.

**Visual Audio**

Many researchers like Harford (1980), schwartz (1980), Preves (1984) demonstrated the clinical potential of miniature mics in earcanal. The development of computerized probe tube microphone assemblies brought in a safe, comfortable, soft invasive silicone tube to measure sound pressure level in ear canal. This development offers significant objective information on the effects of earcanal resonance, diffraction, ear mold occlusion, body baffle, head shadow effects and microphone placement in individual ear canal.

This system allows the clinician to see in reality what physically occurs in ear canal of the patient. Clinical procedure is made easier, faster and reliable.

## PRECAUTIONS

| Visual | Audio |
| --- | --- |
| | During the real ear measurement for hearing aid selection, several precautions have to be considered. |
| Checking the probe and examining the earcanal of the patient. | 1) Prior to testing, the probe tube is checked for holes and/or blockage by wax or moisture. The earcanal also should be checked for wax or any kind of blockage. |
| Insertion of the probe tube into the earcanal of the patient and adjusting it. | 2) During the unaided testing, while probe tube is inserted, care should be taken that it does not cause any damage to earcanal wall or tympanic membrane. |
| Probe tube placement during the aided testing condition can be shown. | 3) During the aided measurements, the earmold should be fitted snuggly in the concha so that low |

**Visual** **Audio**

frequency leakage is minimized. The probe tube is placed along the inferior surface of the earmold and marker is set so that the tube extends 4-5mm beyond the tip of the earmold.

Seating arrangement of the patient can be shown.

4) The case is seated close to the speaker so that reflections and reverbera-tions are minimized.

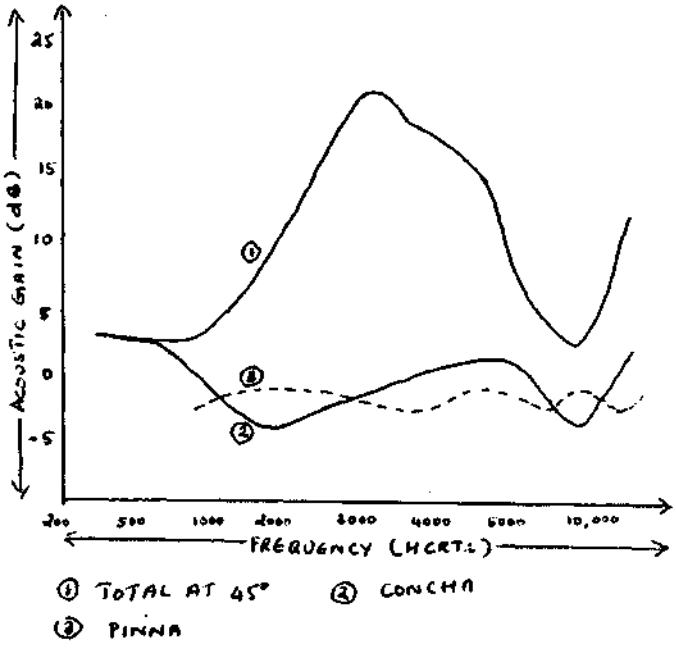
Reflecting surfaces such as walls, tables can be shown

5) Care should be taken to exclude reflection surfaces in the testing condition.

6) Head movements on the part of the patient should be avoided.

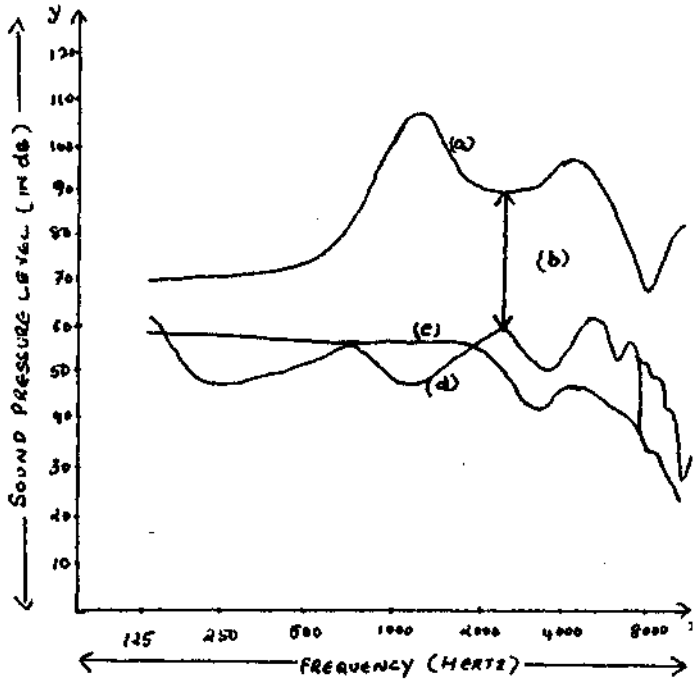
7) Validity can be ensured by rechecking the measurements.

## FACTORS AFFECTING THE REAL EAR MEASUREMENTS

| Visual | Audio |
|---|---|
| A patient seated for insertion gain measurement. | Position of the probe tube in the canal is important and it should always be kept constant especially so while aided and unaided comparisons are made. Head movements on the part of the case should be avoided during testing. |
| Contribution of different anatomical structures of external ear to the pressure gain   | A pressure distribution in a blocked earcanal and open ear canal are different. The open ear canal acts as a standing wave resonator coupled to the free field whereas the blocked ear canal has an uniform sound pressure distribution upto 10kHz. |

## Visual

Ear canal response in occluded and unoccluded conditions.




(a) INSITU GAIN
(b) INSERTION GAIN
(c) INSERTION LOSS
(d) EXTERNAL EAR EFFECTS.

## Audio

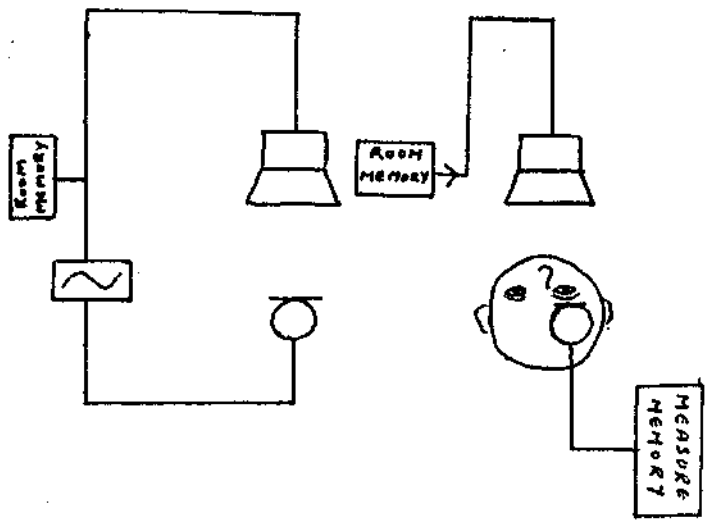
The free field transfer function (external ear effects) should match the receiver and tube resonances for accurate insertion gain measurement. The residual volume that is the remaining ear canal volume between an earmold and the eardrum has significant effect on the insertion gain.

The cavity ranges about 0.4 to 1cm3 in volume depending on size of the ear canal and length of the earmold tip. A small volume results in a higher sound pressure level at the eardrum and a larger volume causes sound pressure level to drop significantly.

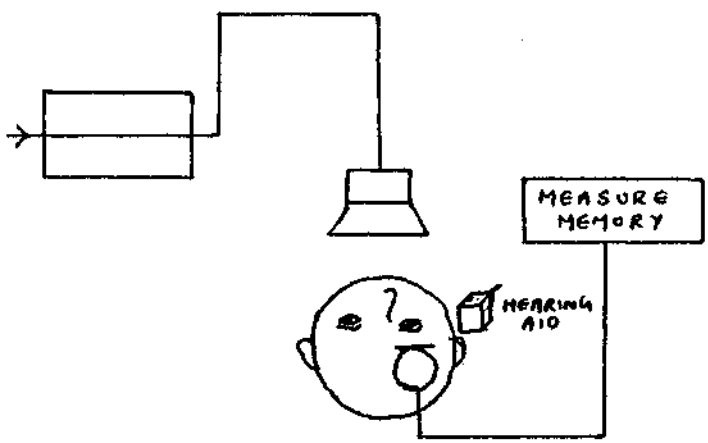
**Visual** **Audio**

INSERTION GAIN TEST PROCEDURE BY SUBSTITUTION METHOD:

UNOCCLUDED CONDITION:




OCCLUDED CONDITION:




point in the sound field and the sound pressure is calculated. This includes diffraction effects of the cases's body, head and hearing aid.

Limitations of this method include:

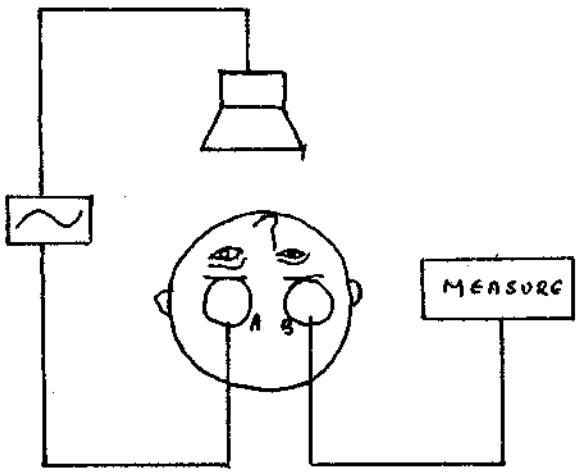
1) requirement of identical measuring conditions.

2) Any movement on the part of the case or ambient conditions result in error.

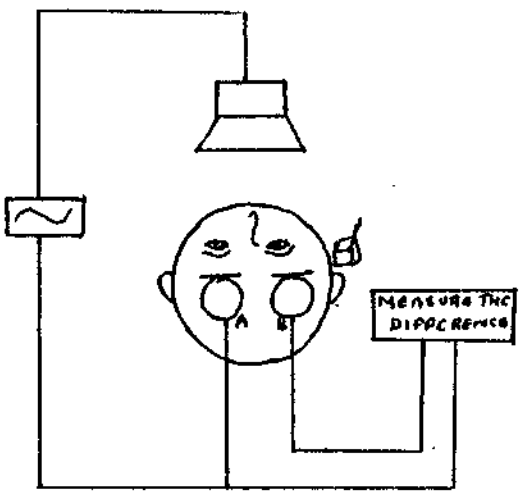
3) Requirement of storage device to store and room calibration and the occluded and unoccluded test results in memory.

## Visual

**Comparison method:**




A → REFERENCE POINT
B → TEST POINT.
'A' & 'B' ARE ACOUSTICALLY AT SAME POINTS.




A → UNOCCLUDED CONDITION
B → OCCLUDED CONDITION.

## Audio

**Comparison method:**

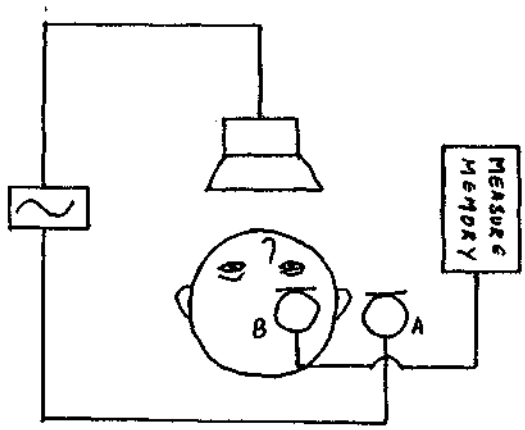
In this method the test microphone are placed simultaneously for free field sound pressure at two acoustically equivalent points in the sound field, that is in each of the two ear canals. Advantage jis that it compensates for variations in ambient conditions and excludes diffraction effects.

The limitation is that it requires two very identical and symmetrical bodies and both should be treated with probe tubes. Case's movements affects the results.

**Visual**

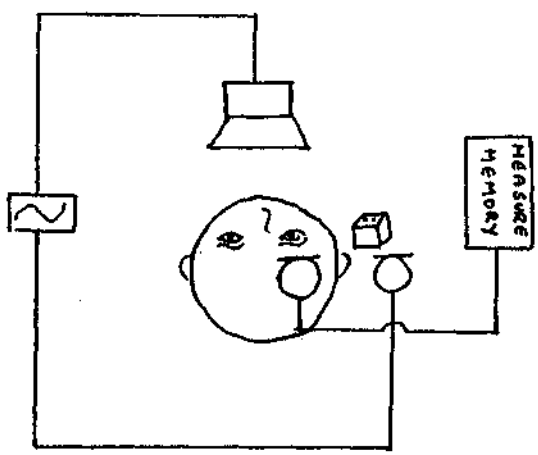
INSERTION GAIN TEST PROCEDURE BY PRESSURE METHOD.

UNOCCLUDED CONDITION:




A - REFERENCE POINT
B - TEST POINT

OCCLUDED CONDITION:




**Audio**

Pressure Method:

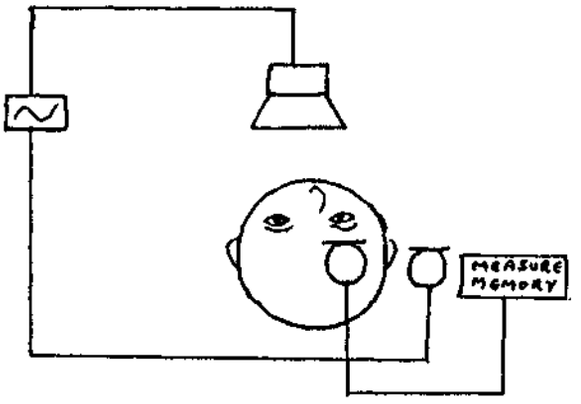
Includes a constant input sound pressure level which is controlled at the point of entry to the ear canal in which the test microphone is situated. The constant controlled input sound pressure level includes a calibrated reference microphone thus eliminating diffraction effects.

Advantages include eliminating the diffraction effects of both hearing aid and the patient's body and it takes care of ambient noise and patient's movements.

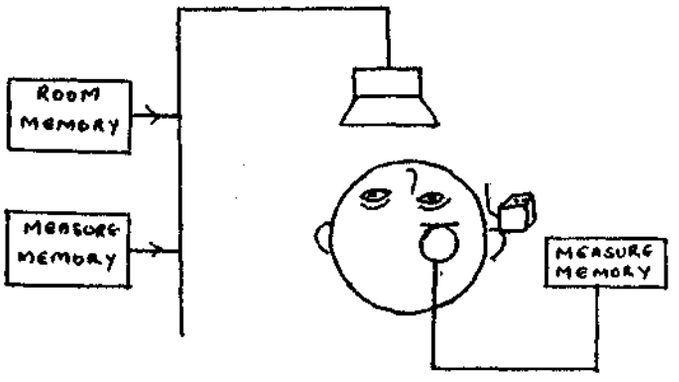
**Visual**

INSERTION GAIN TEST PROCEDURE BY IPSILATERAL COMPARISON METHOD:

UNOCCLUDED CONDITION:




OCCLUDED CONDITION:




**Audio**

Ipsilateral Comparison Method:

This method is a variant of comparison method. The test microphone and the reference microphone are both placed simultaneously at the same point in the sound field in the same ear. Here, the two ears are not considered to be identical. Each ear is tested separately. This method involves measurement and storing of unoccluded ear canal resonance and then the occluded ear test is carried to obtain insertion gain. Advantage of this method is it does not require completely symmetrical body shapes. Head turning will not influence to a greater extent. Only the test requires probe tube

**INSTRUMENTATION FOR INSERTION GAIN OPTIMIZATION.**

**Visual**

Different parts of the equipment can be focussed upon.

**Audio**

The advancement of computerized systems have led to quicker and more objective measures of recording with insertion gain optimization.

The instrumentation consists of probe microphone and video moinitor.Computer-rized probe microphone enable us to measure the changes in sound pressure as small as ldB at the eardrum.

It encorporates entire frequency range rather than a descrete frequency range.

There is no interferen-ce of noise measurement. Computerized measurement saves a lot of time and is efficient.

| **Visual** | **Audio** |
| --- | --- |
| | It also has a speaker with a built in calilbration rod for determining the position of the patient. |
| | Video monitor provides graphic print out on the X-Y axis of the traces. It is possible to have different colour codings to represent different traces. |
| | It is also possible to provide numeric print-out of the frequency sampled and the corresponding respone level in decibels. |
| MADSEN IGO (1000) is in focus. | Modern electronics has come out with an insertion gain optimizer (1GO-1000) with following facilities: |
| | Menu driven operating system which any clinician |

| Visual | Audio |
| --- | --- |
| | can perform without prior knowledge about computer. Instruction for next step or stage comes on the screen. By just pressing the numerals on the key board, one can advance with the steps in testing. A colour screen layout is present and each and every part of the test is displayed on the screen. For some parameters like insertion gain, frequency response, display is not only in terms of numerical value but also as a relative curve. |
| Fonix 6500 is in focus | Fonix Computer controlled real time Analyzer(1988)<br><br>The Fonix 6500 real time analyzer helps in selecting the hearing aid. It has a video display attached to it. |

**Visual**

**Audio**

Hearing aid testing can be performed with this instrument to identify various electro - acoustic characteristics. Hearing aid selection can be carried out by two modes-automatic or manual.

In the automatic mode, unaided, aided conditions can be tested. Insertion gain, insitu gain can be obtained. On the screen, visual display of curves related to unaided/aided insertion, insitu gain along with the target curve is obtained.

As with any hearing aid selection procedure, unaided and aided real ear measurements are done. Before carrying out the test procedure the instrument should be calibrated.

| Visual | Audio |
| --- | --- |
| –> Pressing of stimulus interrupter and highlighting of the frequency range and the type of stimuli used on the screen. | Instead of sinusoidal sweep test frequencies, frequency modulated test sweep or a narrow band noise from 125Hz to 8000Hz is used. |
| –> The test room in which the equipment is placed can be focussed upon. | Test environment is freefield type to maintain a constant sound pressure level at the test site. |
| A chart displaying the preliminary data required for carrying out the real ear measurement | The preliminary data required for carrying out the real ear measurement are:<br>1) Threshold of most confortable level data of the individual.<br>2) Prescription data: Initially audiological tests should be performed and the actual hearing loss of a person should be determined. |

**Visual**

**Audio**

Using any of the prescriptive techniques (POGO, NAL, BERGER) which are programmed in the equipment.

3) We should make a choice between four test methods that is, substitution method, comparison method, pressure method and ipsilateral comparison method.

PROCEDURE

Visual

Administration of the test procedure on a patient can be focussed upon.

Audio

The case is seated and reference microphone and probe microphone are kept in position. Resonance characteristics of the ear canal is obtained.

Hearing aid is placed in the ear. The probe tube

**Visual** Audio

is placed through a channel specially made in the earmold. Normal user gain setting is adjusted and set on the hearing aid. Aided response is noted in this way. Insertion gain curve, aided gain curve appear on the screen.

In the manual mode, same procedure is carried out except that the clinician has to select all the operations for obtaining respective curves.

Insertion gain curve provides a basis for hearing aid selection. The prescrip-tive formulae those can be chosen on this are :

1)NAL

2)POGO

3)BERGER

4)LIBBY'Sl/2 GAIN, 2/3 GAIN AND 1/3 GAIN.

**Visual** **Audio**

If prescriptive formulae are used it is based on the audiogram data which is measured and can be entered in the module.

ADVANTAGES OF REAL EAR MEASUREMENTS:

Visual

A chart displaying advantages of real ear measurements.

**Audio**

The choice of real ear measurement technique for hearing aid selection is preferred by many clinicians on account of the following advantages:-

1) This method offers insitu data from the earcanal of the person, who is a candidate for amplification.

2) The real ear measurements are quick methods and takes only a few minutes for the administration of the test.

| Visual | Audio |
| --- | --- |
| | 3) The transfer formula as in coupler measurements are unnecessary. |
| | 4) All the peaks and valleys of the frequency response are revealed because a sweep frequency tracing is possible. |
| | 5) Need for masking the non-test ear is ruled out since both the ears can be tested separately using this method. |
| | 6) The acoustic modifications when hearing aid and earmold are placed, can be verified. External ear changes can aLso be verified. |

## DISADVANTAGES OF REAL EAR MEASUREMENTS:

**Visual**

A chart displaying limitations of the real ear measurements.

**Audio**

Inspite of all these advantages there are certain limitations which should always be given proper weightage :

1) First of all, there is no standardized instrument for measurement.

2) There is likelihood of obtaining unreliable results and frequency responses above 5kHz.

3) In children, the microphone or probe cannot be accomodated owing to their small canals.

4) Often feed back may occur before the gain level is reached.

| Visual | Audio |
| --- | --- |
| | 5) It is not possible to signify few values such as anti-resonance clips, large peaks etc. |
| | Real ear measurement techniques may need alterations to suit those cases with abnormal external ear. |

## USES OF INSERTION GAIN MEASUREMENT

### Visual

Respective curves can be displayed (in the monitor) using the equipment and charts.

### Audio

Research on how size and volume of the earcanal influence the real ear measurement is warranted.

Real ear measurements are useful to determine :

1) Gain

2) Frequency respone

3) Real ear SSPL 90

4) Quality of frequency response

5) Acoustic modification effects

6) Difference between use gain and full on gain

7) Performance and comparison among hearing aids and

8) Electro acoustical adjustments.

Visual

Audio

But yet it is not desirable to rely on suoh measurements wholly.

Due importance to speech intellegibi1ity tests should be given.

Self-assessment invent-ory or profiles can be used which quantifies the performance with hearing aid in everyday life.

To provide maximum benefit and comfort to the hearing aid user, the real ear measurement technique justify its advantages over the coupler measurements and one can rely on it to a greater extent as compared to coupler measurements.



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