ELECTROACOUSTIC EVALUATION OF HEARING AIDS - LEARN THROUGH AUDIO VISUALS

REG. NO. M 9415

An Independent project submitted as part of fulfilment for the first year M.Sc. (Speech and Hearing) to the University of Mysore

All India Institute of Speech and Hearing
Mysore-570 006

1995

Dedicated to my Dearest Parents

Who have borne all the pains
To give me the best comforts
This would can ever *think o£*

and

Who are responsible for making me
What I am today

CERTIFICATE

This is to certify that the Independent project entitled ***"ELECTROACOUSTIC EVALUATION OF* HEARING *AIDS - LEARN THROUGH AUDIO VISUALS"*** *is a bonafide Work done in part of fulfilment for the first year degree* of *Master of Science. (Speech and Hearing) of the student with* Reg. Wo. M *9415.*

Mysore
1995

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CERTIFICATE

This is to certify that the Independent project entitled **"ELECTR0 AC0USTIC EVALUATION OF HEARING AIDS - LEARN *THROUGH* AUDI0 VISUALS"** *has been prepared under my supervision and guidance.*

Mysore
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Dr. (Miss) S. Nikkam
Guide.

DECLARATION

I hereby *declare that this Independent project entitled* ***"ELECTROACOUSTIC*** **EVALUATION OF HEARING AIDS - LEARN *THROUGH AUDIO VISUALS" is the result of my own study under*** *the guidance of Dr. (Miss) S. Nikkam,Professor and Head Department of Audiology, All India Institute o£ Speech and Hearing, Mysore and has not been Submitted earlier at any University for any other diploma OK degree.*

Mysore. **Reg. No. M 9415**
1995

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INTRODUCTION

Hearing aid is an electroacoustic device used for the amplification of sounds. Hearing aid is a boon to the individual with hearing loss who cannot be helped by either medicine or surgery, and who experience difficulty in one or more of the daily activities either vocationally, educationally or socially. This amplification system merely increases the intensity of the sound reaching the ear and the main purpose of amplification is to utilise the individual's residual hearing to the fullest extent possible. The advancement of hearing aids miniaturisation and quality improvement has, not only led to more satisfaction on the part of the client, but also more contentment on the part of the clinicians. Many hearing aid manufacturing companies have come up with different types of hearing aids of mild, moderate and strong categories. Hence it is very essential for the clinician to have information regarding the electroacoustic characteristics and the measurement of these in order to prescribe suitable hearing aids for these clients.

Electroacoustic measurements

What is electroacoustic measurement ? The hearing aid converts acoustic energy into electrical energy, amplifies it and then converts it back into acoustic energy. The study of changes taking place in the hearing aid as energy is transduced is known as electroacoustic measurement.

The term electroacoustic measurement includes the generation and reception of sound wave through electro-mechanical system or transducers. The operational characteristics of any electroacoustic device measured precisely will define its nature and performance to distinguish the make and type from the other. During recent years, therefore many measurement standards and practices have been established, and many types of sophisticated real time computerised instruments have been developed to carry out these measurements.

Electroacoustic measurements of hearing aid basically constitute a variety of measurements including saturation sound pressure level, gain, frequency response, etc. These measurements give an insight about the quality of the product being produced and used.

Purpose of electroacoustic measurement

The primary purpose of measuring electroacoustic characteristics of hearing aids are;

1. Electroacoustic measurements help us to compare the characteristics of different hearing aids and

thus help us in selecting a suitable hearing aid for an individual.

2. It helps us in knowing the performance characteristics of a hearing aid and to see whether the hearing aid is performing according to the manufacturer's specification.

3. Electroacoustic measurements helps in categorising the hearing aids into strong, moderate and mild categories. Electroacoustic measurements help us in confirming whether the electroacoustic characteristics are according to the recommended standards. This helps us in detecting whether the different parameters exceed the value which is recommended in national standards.

4. Electroacoustic measurements monitor the performance of the hearing aids after repair. After the repair, measurements of the electro-acoustic characteristics, can be made to check whether it is performing as it was supposed to.

5. It monitors the performance of the hearing aid, that is, helps in the measurement of parameters which changes with use. For example, distortion may increase with use.

6. It helps in studying the effect of acoustic and electronic modifications in the hearing aid.

7. Electroacoustic characteristics can also be used for the quality control of the hearing aid.

Instrumentation for electroacoustic measurements

The ability to accurately measure the performance of a hearing aid is important to the manufacturer, clinician, researcher and consumer. To satisfy all of these groups with a single measurement system, is a desirable goal but the increasing complexity of hearing aids (Hecox and Miller, 1988; Levitt, 1987; Mehon, 1989) present several obstacle including noise reduction technique (Weiss, 1987, Preues, 1990) lack of standard for signal processing, etc. However it may be pointed out that it still needs a lot of talent and insight to translate the objective results into subjective domain. It is recognised that the knowledge of the electroacoustic performance of the hearing aid system is essential to understand . each specific hearing aid capabilities. Hence, for this purpose, measurements need to be carried out in a proper environment as specified in the national or international standards in order to ensure reliable or valid measurement. The electroacoustic measurement instrumentation includes anechoic chamber and appropriate associated electronic instruments. Certain variables like temperature,relative humidity, reverberation, atmosphere presure,etc. affect electro-acoustic measurement. Appropriate levels of electric and magnetic fields also act as influencing factors in the measurements.

The purpose of this Independent project is to provide guidelines on the electroacoustic measurement, electroacoustic characteristics, the various instruments used, variables affecting electroacoustic characteristics and also to compare the electroacoustic characteristics when different standards are used.

History

During early period of electric and electronic instrumentation there was a total lack of standardisation of performance parameters, how to measure and report them. Romanow (1942) and Carlisle and Mundel (1944) produced among the earliest extensive reports on hearing aid electro-acoustic measurements. Then a -Committee of the American Hearing Aid Association compiled a tentative code for measurement of performance of hearing aids (Kranz, 1945). But this was not very comprehensive and widely accepted in the industry.

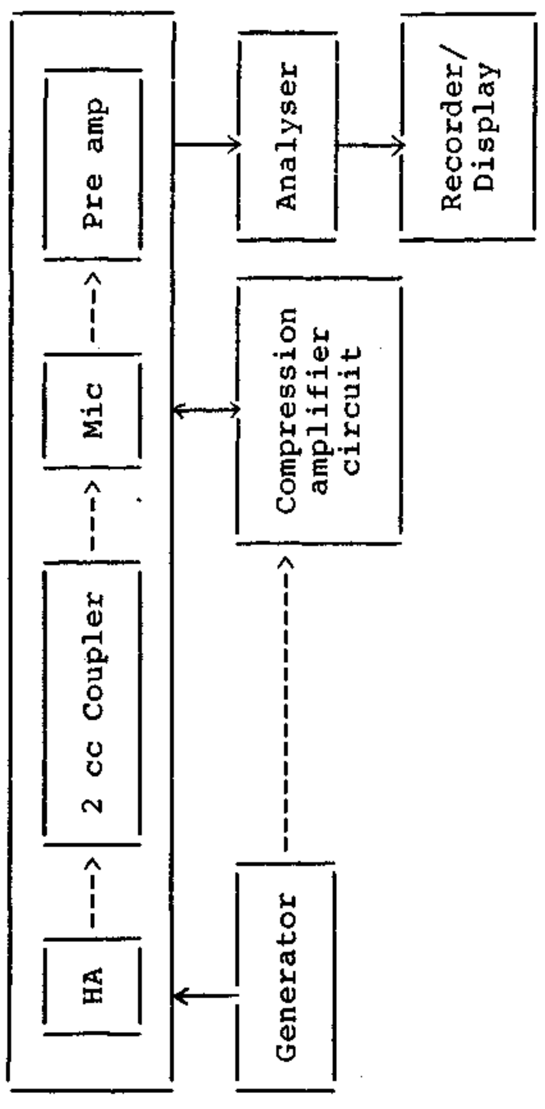
The International Electrotechnical Commission (IEC) in 1959, published their recommended methods for measurements of electroacoustic characteristics of hearing aids. Later this was modified and adopted by the American National Standards Institute as American Standard S. 3.3-1960, "Electroacoustical Characteristics of Hearing Aids" (ANSI, 1960). The Hearing Aid Industry Conference (HAIC, 1961) adopted the Hearing Aid Industry Conference standard method of expressing hearing aid performance. Later this Hearing Aid Industry Conference (HAIC) standard was modified and was adopted as ANSI standard S. 3.8-1967, Method of Expressing Hearing Aid Performance (ANSI, 1967). So from the standards it is seen that the International Electrotechnical Commission and Early ANSI standards describe how to measure performance while the Hearing Aid Industry Conference and later ANSI standards specify not only how but what to measure. As Berger (1974) states "advertising slogans were the rule rather than statements based on scientific fact".

CHAPTER 1

INSTRUMENTATION ON ELECTROACOUSTIC MEASUREMENTS

The measurement of electroacoustic characteristics of a hearing aid is a complicated and confusing task especially for the beginners. Hearing aid characteristics are measured in a 2 cm^3 hard walled coupler or Zwislocki coupler or in a KEMAR.

Slide 1



Electroacoustic measures are basically measurements of input-output function. It gives us an idea of how output differs from the input signal. So there should be a means for generating and specifying an input signal and of measuring the output from the hearing aid. Traditionally used instrumentation for electroacoustic measurements is shown in the slide.

Slide 2: IGOHAT 1500
Slide 3: FONIX 6500C
Slide 4: Audiotest station

Now we make use of the computerised real time equipments for the measurements of electroacoustic characteristics. The instruments used are Madsen IGOHAT 1500 and Fonix 6500C and audiotest station. With the availability of automatic computerised instrument, the measurements are carried out just with a button press.

Slide 5: Hearing aid test box

Hearing aid test box is an anechoic space which is free from reverberation and variation. The instrument included in hearing aid test box are: hearing aid, mic, 2 cc coupler and preamplifier. The hearing aid test box also contains loud speaker which transduces the signal.

Slide 5: Hearing aid
(REPEATED)

Focus on the hearing aid

The hearing aid to be tested is placed in a hearing aid test box. The microphone of hearing aid to be tested should be placed within the test space at a position close to reference recommended. The hearing aid microphone should be placed in a position so that it faces the sound source. The tone control should be at 'N' position and volume is adjusted to RTG position or full on position based on the characteristics to be measured.

Slide 6: Couplers HA1 and HA2

A coupler is a cavity of pre-determined shape and volume which is used for electroacoustic measurement of earphones in conjunction with a calibrated microphone adopted to measure the pressure developed within the cavity. IS 10776 (part 1) (1984). Commonly used couplers for the electroacoustic measurements are the HA1 and HA2 couplers. HA1 is used for the electroacoustic characteristic measurement of hearing aids with earmolds and HA2 without earmolds.

System calibration

In order to obtain an accurate measurement of the hearing aid in the test box, the output of the measurement system should be adjusted so that the system gives the same reading as that of the output level of the calibrator.

Slide 5: Microphone
(REPEATED)

Focus on the microphone

There are mainly two microphones in the test space. One microphone which monitors the input SPL at the hearing aid microphone and another receives the input from the hearing aid via 2 CC coupler. With regard to the test microphone and reference microphone there are mainly four methods for the electroacoustic measurement. These methods are substitution method, comparison method, pressure method and simulated in situ methods.

Slide 7:
Substitution method
Comparison method
Pressure method
Simulated in situ method

Substitution method

This is a method of measurement in which the hearing aid and the microphone employed to measure the free field sound pressure are placed alternatively at the same point in the soundfield. IS:10776 (part 1) (1984).

Comparison method

This is a method of measurement in which the hearing aid and the microphone employed to measure a free field sound pressure are placed simultaneously at two different points symmetrical with respect to the axis in the sound field. IS: 10776 (Part 1) (1984).

Pressure method

This is a method of measurement in which the input sound pressure level is controlled close to the sound entrance opening of the hearing aid by a pressure Calibrated controlling microphone, thus substantially eliminating the diffraction effects from the hearing aid. IS:10776(Part1)(1984).

Simulated in situ method

This is a method of measurement in which the hearing aid is mounted upon an artificial head and torso in order to simulate the acoustical effects of an average adult wearer IS.-10776 (Part 1) (1984).

Block 6 & **7 of Slide 1: Loudspeaker and compression amplifier** (REPEATED)

The electrical signal from the oscillator drives the loudspeaker in the test box to produce an acoustic signal. The regulating microphone system measures the SPL in the test space and if the oscillator compressor is activated, a constant input intensity is maintained irrespective of the frequency changes.

Block 9 of Slide 1: Analyser (REPEATED)

It analyses the output of the hearing aid in terms of the sound pressure level (SPL) at different freuencies.

Block 10 of Slide 1: Recorder/Display (REPEATED)

The results of the analysis can be displayed on a video monitor and/or can be recorded.

CHAPTER 2

ELECTROACOUSTIC CHARACTERISTICS

The changes seen in a hearing aid as the sound is transduced from acoustic to electric to acoustic energy are known as electroacoustic characteristics. The various electroacoustic characteristics discussed here are the saturation sound pressure level 90 (SSPL 90). Full-on gain, reference test gain, frequency response, frequency range, harmonic distortion, equivalent input noise, induction coil sensitivity and current drain. Coming to each of the parameters one by one.

Slide 8: Saturation sound pressure level 90 Saturation sound pressure level 90 is the maximum of sound pressure level, a hearing aid can produce regardless of the gain and intensity of the input signal. When there is an increase in the input signal, the output also increases linearly upto a point. Beyond this particular level of the input, the output remains the same. Usually in most of the hearing aids at an input level of 90 dB SPL saturation occurs. This output is known as SSPL 90 curve.

Slide 9: Full-on gain Gain of the hearing aid is the SPL difference between the input and the output level of the signal. For eg. If the input is 50 dB and output is 80 dB, then the acoustic gain is 30 dB. The gain measured with the hearing aid at full on position is called the full-on gain. For linear hearing aids, the level of the input is 60 dB but for AGC it is 50 dB.

Slide 10: **Reference test gain** Reference test gain setting is established using an input sound pressure level of 60 dB. Here the gain control is adjusted such that the average of 1 kHz, 1.6 kHz and 2.5 kHz gain value is equal to (HFA SSPL 90-60 dB-17 dB) $\pm$ 1 dB. The reference test gain position gives a more realistic approximation of a probable use setting. The rationale behind this measurement is that the average sound pressure level is 60-65 dB. But there are peaks in these curves. The peaks in speech will be 17 dB above the average sound pressure level (ANSI). According to Indian Standards (IS) it is 15 dB.

Slide 11: Frequency response and frequency range

The sound pressure level developed at different frequencies in the acoustic coupler by the hearing aid for a constant input level, is expressed as a function of frequency and the output intensity. There can be a series of curves for a number of input levels. These curves reflect the input/output characteristics of the hearing aid. This is the basic frequency response. A family of curves can be got by changing the input level. This family of curves represent the comprehensive frequency response. From the basic frequency response curve, find out the average level of 1 kHz, 1.6 kHz and 2.5 kHz. Mark this value on the Y-axis. Then subtract 20 dB from this and mark another point on the Y-axis. From this point, draw a line parallel to the X-axis. This line intersects the basic frequency response at two points. The frequency point towrads the left of 1 kHz is the low frequency cutoff and towards the right is the high frequency cut off of the frequency range of the hearing aid.

Slide 12: Harmonic distortion

When the output is not an exact replica of the input, the signal is said to be distorted.

$$\text{Total harmonic distortion} = \sqrt{\frac{P_2^2 + P_3^2 + \ldots}{P_1^2 + P_2^2 + \ldots}}$$

where,

P1 - Sound pressure of fo

P2,P3 - Sound pressure of harmonics

This harmonic distortion occurs due to the presence of harmonics along with the fo in the output for a particular input frequency. It can be expressed in dB or in %.

Slide 13: **Intermodulation distortion**

If more than one frequency is given as input, the output will have additions and subtractions of these frequencies given. This is also expressed in decibels, or in percentages. Intermodulation difference frequency distortion arises due to the non-linearity in the hearing aid.

Slide 14: Equivalent input noise level

It is the magnitude of the internal noise generated by the hearing aid even when there is no input given to the hearing aid. Equivalent input noise is measured to see if the internal noise affects the output when there is an input.

Slide 15: Induction coil

The hearing aid is placed in a 1 kHz alternating magnetic field with a field strength of 10 mA/m after putting the hearing aid in 'T' position and volume control to full on.

Slide 16: Current drain

The current drawn by the hearing aid from a cell is the current drain. The magnitude of current drain depends on the category of the hearing aid. A strong category hearing aid draws more current and a mild category hearing aid draws less current. Thus the life of the battery is lesser with a strong category aid than a mild hearing aid.

Slide 17: ***Condensed outline of tests on electroacoustlc*** **characteristics**

Characteristic	*Input SPL (dB) re20uP$_a$*	*Frequency (Hz)*	*Gain control setting*	*Presentation*	*Tolerance requirements*
SSEL90 (saturation)	*90*	*200-8000*	*Full on*	*Curve*	*Basic test equipment tolerance*
Maximum SSP90	*90*	*Any frequency between 200 & 8000*	*Full on*	*Number (dB)*	*Mfr. to state max. value for model*
Average SSPL90	*90*	*1000,1600,2500*	*Full on*	Number *(dB) (3 freq. average)*	*± 4 dB*
Average full-on gain	*60 or 50 (state which) 50 for AGC*	*1000,1600,2500*	*Full on*	Number *(dB) (3 freq. average)*	+ 5 *dB*
Reference test gain control position	*60*	*1000,1600,2500*	*Set gain control back to give output SPL 17 dB less than average SSFL90, or full on for low gain aids*		*17 ±1 dB*
Frequency response	*60 (linear) 50 (AGC)*	*200, 5000 or to 20 dB below 3 freq. avg.*	*Reference test position*	*Curve*	*Low band* + 4 dB *High band +_6 dB*
Total harmonic distortion	*70*	*500,800,1600*	*Reference test position*	Number *(%)*	*Mfr. to stage max. value for model*

Slide 17 (Coatd.)

Characteristic	Input SPL (dB) re20uP[3]	Frequency (Hz)	Gain control setting	Presentation	Tolerance requirements
Equivalent *input noise level, L.*	*65*	*1000,1600,2500 (avg. to get L_{av})*	*Reference test position*	Number(dB^ *Ln* = Lp(Lav60)	*Mfr. to stage max. value for model*
Telephone pickup (induction coil)	*10 mA m rms magnetic field*	*1000*	*Full on*	Number *(dB)*	*Within ±6 dB of mfr's specified value*
Battery current	65	*1000*	*Reference test*	Number*(dB)*	*Not to exceed mfr's*
Input-output curves *(AGC only)*	*50 to 90*	*2000 -*	*Full on*	*Curve input-abscissa output-ordinate*	*specified maximum for the model*
Attack and release times *(AGC only)*	*Abrupt 55 to 80 80 to 55*	*2000*	*Full on*	Numbers Cms)	*To be within + 5 msec, or + 5% of* values *specified by mfr.*

* *Reference test gain control positio*ri *for AGC aids* is full an.

** *L2,* is the *noise reading in the coupler with the input signal.*

CHAPTER 3

VARIABLES AFFECTING ELECTROACOUSTIC CHARACTERISTICS MEASUREMENTS

Slide 18: Test environment

An Audiologist should have an insight about where to make the measurement. A room with low noise level and few reflective surfaces will be an ideal condition. Humidity, temperature and pressure should be within the specified range.

Slide 19: Loudspeaker azimuth and distance

The exact location of the loud-speaker relative to the hearing aid is another variable. Most of the manufacturers recommend 0° or 45° azimuth. The effects of head diffraction and body baffle changes as the signal source moves from 0° to 90°. But the changes in electro-acoustic measurements due to loud-speaker azimuth are restricted to frequencies above 2 kHz.

Slide 20: Earmold modification

Earmold acts on the delivered output of the hearing aid receiver. The changes in electroacoustic characteristics depending upon the earmold configuration is shown in the slide.

Slide 21: Stimulus (type and level)

Stimulus can be sweep frequency pure tones, warble tones, clicks, wide band noise, narrow band noise or speech noise. Most of the units can deliver signals from the loudspeaker over a 50-90 dB sound pressure level range. Signal level depends on the purpose of measurement.

Slide 22: Distortion

If a high input sound pressure level is given, then distortion occurs. Noise in the hearing aid along with the other factors contribute to distortion if it is more than the specified limit.

Slide 23: Body baffle and head diffraction

When a hearing aid is worn on the body its response gets changed by the body clothing and head diffraction (reflection and absorption of sounds).

Slide 24: Battery life

When a battery is newly put there is an overshooting effect (the input will be more)

$$\text{Battery life} = \frac{\text{Batery capacity}}{\text{Battery current drain}}$$

If you consider this ratio, it is seen that based on the requirement the battery life changes. As the output of the hearing aid increases, the battery drain also increases. As the age of the battery increases, the battery capacity reduces. This affects the hearing aid performance or the output.

Slide 25: Real ear to coupler difference

Another important variable which has to be kept in mind is the real ear to coupler difference. Even-though it also contains a volume of 2 cm there is a difference between the sound pressure level developed in real ears and couplers. This may be because the acoustic compliance is more in a coupler compared to real ear. The figure shows the difference between the sound pressure level developed in the real ear and Zwislocki coupler.

BIBLIOGRAPHY

1. American National Standards Institute (1960). Electro-acoustic characteristics of hearing aids, American Standard, S.3.3-1960, New York, ANSI.
2. Beattie, R.C. (1988). SSPL selection: A clinical protocol, Hearing Journal, No. 41, 18-23.
3. Cox, R.M., Gilmore, C. (1990). Development of profile of hearing aid performance. Journal of Speech and Hearing Research No. 33, 34-37.
4. Curran, J.R. (1974). Harmonic distortion and intelligibility, Hearing Aid Journal, No. 27, 12-39.
5. Ely, W.G. (1973, 1978). Hearing aid battery life, Hearing Instrument, No. 29, 12-14.
6. Hawkins, D.B. and Yacullo, W.S. (1984). Signal to noise ratio advantage of binaural hearing aids and directional microphone under different levels of reverberation, Journal of Speech and Hearing Disorders, No. 49, 278-286.
7. Kasten, R.N. (1977). "Electroacoustic characteristics" p. 44-45. in Hodgson, W.R. and Skinner, P.K. "Hearing aid assessment and use in audiologic habilitation", Baltimore, The Williams and Wilkins Company.
8. Killion, M.C. (1993). Transducers and acoustic coupling: The hearing aid problem that is mostly solved, p. 31-49. In Studebaker, G.A. and Hockberg, J., "Acoustical factors

affecting hearing aid performance". Needham Heights, Allyn and Bacon.

9. Lybarger, S.F. (1961). Standard hearing aid measurement, Audecibel, No. 10, 8-10, 24-25.

10. Pollack, M.C. (1980). Electroacoustic characteristics, p. 40-70, In Pollack, M.C, II Edition, "Amplification for the Hearing Impaired, New York, Grune and Stratton.

11. Ravishankar, K.C., Shashidhar, K.N. (1988-89). Electro-acoustic performance of hearing aids, Journal of Indian Speech and Hearing Association, No. 2, 5-6.

12. Stelmachowicz, P.G., Lewis,D.E., Serwald, R.C., Hawkins, D.B. (1990). Coupler and pure tone signals in the evaluation of hearing aid characteristics, Journal of Speech and Hearing Research, No. 33, 380-385.