Intermodulation Distortion Test For Differentiating Among Indian Hearing Aids

ANNE

AN INDEPENDENT PROJECT SUBMITTED IN PART FULFILMENT FOR

THE III SEMESTER M.Sc. (SPEECH AND HEARING),

UNIVERSITY OF MYSORE

1980

CERTIFICATE

This is to certify that the independent project Entitled "intermodulation Distortion Test for Differentiating among Indian Hearing Aids" is the Bone fide work in part fulfillment for III Semester M.Sc. Speech and Hearing, Carrying 50 marks, of the student with register no.

Director i/c,

All India Institute of Speech and Hearing

Mysore - 6

CERTIFICATE

This is to certify that this independent project has been prepared under my supervision and guidance.

Guide

DECLARATION

This independent project is the result of my own study under taken the guidance of Mr. M.N. Vyasamurthy, Lecturer in Audiology, All India Institute of Speech and Hearing, and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore   Register No. 8 (Eight)

Date:

ACKNOWLEDGEMENTS

I wish to express my heartfelt gratitude towards Mr. M.N. Vyasamurthy, Lecturer in Audiology, All India Institute of Speech and Hearing, for his invaluable guidance and constant encouragement throughout this investigation.

I am indebted to Dr. N. Rathna Director i/c, Professor and Head of the Department of Speech Pathology for his kind assistance and suggestions.

I thank Dr.(Miss) S.Nikam, Professor and Head of the Department of Audiology, for her valuable assistance in rendering the necessary facilities.

I am truly grateful to Mr. N.P. Nataraja, Lecturer in speech Pathology, and Mr.P.Chandra, Clinical Assistant, for their timely help.

My most sincere gratitude to Mr.S.S.Murthy, Lecturer in Electronics, and Mr.Narayan Raju, Electronics Engineer, for their ingenious technical operations and assistance at various stages of the study.

I am grateful to Mr.Jayaram, central Institute of Indian Languages, Mysore, for his valuable statistical suggestions in solving the data. And I am most grateful to all those who were the subjects for this study and others who have assisted me in this work.

CONTENTS

LIST OF FIGURES

Statistical Analysis:

CHAPTER - I

INTRODUCTION

A hearing aid can be described as any device that brings sound to the ear more effectively. In the narrower and most frequently used sense, the modern hearing aid is a miniaturized amplifier circuit which, though it takes many forms, is designed specifically for improving human hearing. The function of the hearing aid is to amplify sound energy and to present the amplified sound to the ear with as little undesirable sound as possible. Since sound cannot be amplified directly, it is necessary to charge the acoustic energy to an electrical signal. This electrical signal is them amplified and again converted to acoustic energy at the ear.

Even though the hearing aids look alike physically, they may differ widely in their performance. The performance of the hearing aids depends upon certain characteristics like:

(a). Frequency response

(b). Acoustic gain

(c). Amount of distortion

(d). Size and weight

(e). Extraneous noise

(f). Flexibility and adjustability to individual needs.

(g). Sensitivity and

(h). output limiting action (A.V.C).

A fine hearing aid in miniature size achieves the most possible desirable balance between the above mentioned characteristics.

It is a known fact that even when a hearing aid is perfect in

Its characteristics, the performance of it can be significantly altered when it is coupled to a system (ear mould) or to an individual's ear. Hence, audiologists usually prescribe a hearing aid only after a trial on the individual's ear/s.

Carhart (1950) regarded the problem of hearing aid selection as the most controversial aspect of clinical audiology. Audiologists disagree on the methods to be used in a hearing aid evaluation, on the type and reliability of the signals to be employed on the electro acoustic characteristics suitable for different hearing impaired populations, and on whether the dividends in present day selection procedures justify the clinical efforts.

Because of some areas of disagreement, several methods have been recommended by different investigators for hearing aid evaluation and prescription. The usual practice is to evaluate from three to six hearing aids. Some investigators suggest a hearing aid evaluation procedure on unaided and aided performance in terms of effective gain, tolerance limit, efficiency in noise and word discrimination (Carhart, 1946). Other investigators have noted the increased information and sensitivity which can be derived from other types of speech signals, such as a rhyme type test (Bode, Tyszka, Johnson, Walden, and Wanska, 1968) and a synthetic sentence test (Jerger and Thelin, 1968).

On the other hand, subjective preferences have been included as one criterion in hearing aid evaluation. Many clinicians

Commonly ask their clients to express relative preferences among aids. Jeffers (1960) used a quality Judgement paired comparison method to assess differences among hearing aids. Jerger (1967) describes an intermodulation distortion test (IDT) for differentiating among hearing aids. The IDT procedure appears to merit consideration by clinicians seeking to explore new ground in hearing aid evaluation procedure.

Purpose of the Present study.

A historical perspective of hearing aid selection procedures reveals that many such procedures have been developed utilizing different methods, signals, materials and testing conditions. However, the procedures employed in the clinics in India will again depend on the time and effort involved and the differing conceptions of the audiologist's role regarding hearing aid selections.

In such a situation like this, it was thought important to develop a hearing aid selection procedure most applicable for differentiating among Indian hearing aids. Since the IDT appears to merit consideration by clinicians, it was thought that the IDT would help seek now ground in hearing aid evaluation procedures.

Thus the present study was an attempt to apply the IDT clinically for differentiating among Indian hearing aids. This would then reflect meaningful hearing aid performance differences.

Objectives of the study:

The objectives of the present study are as fellows:

1) To apply the IDT procedure clinically so as to differentiate among the Indian hearing aids, thus enabling simplification in hearing aid selection procedures.

2) Finding the performance of normal on this test.

Brief plan of the study:

Two pure tones, one at 1000Hz and the other at 1500Hz were recorded on each channel of a two-channel tape recorder, on one of the channels, the signal was ‘clean’ and on the other channel, the signal was a hearing aid processed one, under a constant tone control setting, gain and input level.

The subjects were made to listen alternately to the signal pairs under just one noise condition. Their task was to determine whether they perceived the signal quality between the ‘clean’ signal and the hearing aid processed signal as the same or different.

Available clin ic hearing aids were used, namely,

1. Arphi super
2. Arphi Extra super
3. Arphi Universal
4. Elkon 6903
5. Rionet H536

The data collected was then statistically analyzed.

Hypothesis of the study:

There exists no difference between the 'clean' signal and the hearing aid processed signal.

Definition of the terms used:

Distortion: Inexact reproduction of a sound wave pattern.

Intermodulation distortion: Intermodulation distortion occurs when the output signal contains frequencies which are arithmetic sums and differences of two or more input frequencies. It in the result of amplifier non-linearity when 2 or more signal frequencies (as in speech) are applied simultaneously at the input. Speech intelligibility can suffer in the presence of intermodulation distortion due to unwanted frequencies distorting the primary message signal.

Limitations of the study:

1) All the Indian hearing aids were not included for the study due to non-availability of hearing aids in the Institute.
2) The procedure was extended to sample an aid's performance under a constant tone control setting, gain and input level and in the presence of one noise condition.

Implications of the study:

1) The IDT helps to sample an aid's performance on intermodulation distortion.
2) It helps the clinician to select the proper hearing aid/s for trail.
3) The wastage of hearing aids by stocking them in the clinic can be eliminated.
4) This information would be useful to the manufacturers of the Indian hearing aids as they have not been subjected to this kind of test.

CHAPTER – II

REVIEW OF LITERATURE

A hearing aid is an instrument that brings sound more effectively to the listener's ear (Niemoller et al., 1970). It may simply collect sound energy from the air, it may prevent the scattering of sound during transmission or it may provide additional energy usually from the battery of an electrical amplifier. The major objective of a hearing aid is to make speech intelligible.

Prior to the invention of electrical hearing aids, various other hearing "aids" were used; such as; hand cupped behind the ear, animal horn or broken seashell, speaking trumpets or hearing trumpet etc.

Now, with the advent of electronic amplification an electro acoustic engineering, it is possible to deliver as much sound as the ear can tolerate so that the hearing aid delivers sound loudly enough to be heard easily without discomfort. All electronic hearing aids basically operate on the same principle. In a broad sense, a hearing aid in any device that more effectively brings sound to the ear. A modern hearing aid is an amplifier whose function is to the ear with as little distortion as possible. Since the acoustic energy of sound cannot be amplified directly it is necessary to convert it into an electrical signal. This signal is amplified and then changed into acoustical energy.

Even though the hearing aids look alike physically, they may differ widely in their performance. The performance of the hearing aids depend upon certain characteristics like:

a) Frequency response
b) Acoustic gain
c) Amount of distortion
d) Size and weight
e) Extraneous and adjustability to individual needs
f) Output limiting action (A.V.C)

A fine hearing aid in miniature size achieves the most possible desirable balance between the above mentioned characteristics.

It is a known fact that even when a hearing aid is perfect its characteristics, the performance of it can be significantly altered when it is coupled to a system (ear mould or to an individual's ear. As early as in 1940, it was suggested that alterations in the ear piece would cause a reduction in low frequency amplification. A vent in the ear mould can reduce low frequency amplification. When the ear mould does not fit snugly and if there is an acoustic leakage, then again it attenuates extreme low frequencies and even alter the hearing aid response pattern. Further, the volume of air between the tip of the canal aperture and the tympanic membrane can produce variations in hearing aid performance. Hence, audiologists usually prescribe a hearing aid only after a trial on the individual's ear/s.

A. Hearing Aid Selection:

Assistance in the selection of the hearing aid is an integral and important role of the audio logical program. Carhart (1950) regarded the problem of hearing aid selection as the most controversial aspect

Of clinical audiology. Many, if not most, audiologists are dissatisfied with current practices and procedures in hearing aid selection. Audiologists disagree on the methods to be used in a hearing aid evaluation, on the type and reliability of the signals to be employed , on the electro acoustic characteristics suitable for different hearing-impaired populations, and on whether the dividends in the present day selection procedures justify the clinical efforts.

The disagreement among various audiologists with procedures in hearing aid selection may be attributed to the following:

1) Hearing aid selection is a time consuming process
2) Hearing aid selection requires considerable knowledge
3) Hearing aid selection are often boring and frustrating
4) Hearing aid selections are not profitable.

Many words continue to flow across the pages of professional journals discurring best methods to use in selecting aids for the hearing-impaired. In fact, all attention has been focused on choosing among various philosophies of hearing aid selection.

Many audiologists find that the basic procedure used to explore each patient's performance with those particular hearing aids expected to be suited especially to his needs. The process is continued until the clinician feels a satisfactory solution to the patient's communicative problem has been released. If the solution involves the use of wearable amplification every effort is made to recommend a specific hearing aid.

The usual practice is to evaluate from three to six hearing aids. The clinician must be thoroughly familiar with the published.

Characteristics of each; some clinics are able to supplement and confirm the manufacturer's specifications with their own instrumentation. As much as possible, each aid has to be checked to ensure that it is working properly. Clinicians may be dismayed to find themselves with a closet full of hearing aids, many of which they cannot use. The dealer of manufacturer would not be expected to place in clinics hearing aids which are not used in evaluation a reasonable number of times and which are not recommended with a certain amount of consistency. This would represent a poor investment for the dealer and certainly holds no attraction for clinicians. Thus the audiologists need an objective means of evaluation to determine which instruments should be retained and which are merely "gathering dust".

Zink (1969), Zink and Alpines (1968) and Ross (1975) suggest that an electro acoustic hearing aid evaluation supplement, and sometimes substitute for, conventional hearing aid evaluations. Each new aid is assessed electro acoustically to determine if the instrument meets basic standards in respect to gain, gain control linearity frequency response, frequency range, distortion and output. Only these aids which meet the electro acoustic standards (not explicitly specified) are included in the conventional hearing aid evaluation. For children whose language inabilities make conventional procedures impossible, the electro acoustic hearing aid evaluation is used to directly select the hearing aids which suits to their presumed needs. Considering the paucity of electro acoustics applied in many hearing aids specifications, the variability of electro acoustic characteristics among aids of the same make and model, the necessity to check aids over time, the routine use of electro acoustic instrumentation can give the clinician a firmer foundation on which to base and modify his clinical judgements.

Janet Jeffers and Curtis R. Smith (1964) believe that audiologists who cannot find reliable differences among hearing aids are audiologists who have not taken the time to master their stock, who are unable to devote adequate time to the selection procedure and, as a result, do not try enough aids on a given patient, or who attempt short cuts with respect to the length of list. Therefore, one of the audiologist's most important contributions to the rehabilitation of the hearing handicapped is his knowledge knowledge of hearing aids and his ability to select the ones appropriate for trial, with any given patient, out of the sores of aids and hundreds of combinations available to him.

By making determinations and preparations in advance, only then can the clinician concentrate his attention on the client.

The recognition of the importance of psychoacoustic evaluation of hearing aids, has paved way for the recommendation of several methods by different investigators for hearing aid evaluation methods by different investigators for hearing aid evaluation and prescription.

In 1943, Hughson and Thompson made the first evaluation of selective fitting of hearing aids.

In 1946, Weiner and Miller suggested a hearing aid evaluation procedure which included monaural tests of the patient without a hearing aid which included thresholds for pure tones and for speech, tolerance for pure tones and for speech and articulation tests with suitable word lists.

In 1946, Raymond Carhart used a twelve step procedure for hearing aid evaluation. Four dimensions of the hearing aid performance were explored, effective gain, tolerance limit, efficiency in noise and word discrimination.

In step one, the subject's unaided sound-field SRT, tolerance limit and discrimination score (Pb-50s 25dBSL) were measured. These scores served as the reference for comparison with aided performance.

In step two, the gain control of the first instrument was adjusted until the subject reported that a 40-dB HTL speech signal was at the MCL level. An aided SRT and TD were then measured.

In step three, the aid was set on maximum gain and the aided SRT and TD were again measured.

In step four, the gain control was adjusted to permit the subject to reach an MCL level with a 50-dB HTL input speech signal. Two signal-to-noises were obtained, one with white noise and the other with saw tooth noise. The intensity of the noise was alternately increased and decreased until a point was reached where the subject could barely repeat several test words. The difference between the speech and the noise levels at this point defined the signal-to-noise ratios.

In step five, the aid was again adjusted to permit the subject to reach an MCL level, this time with a 40-dB HTL input speech signal. The aided SRT was again measured for a reliability check against step two. A 50-word intelligibility test was administered at a 25-dB SL.

Steps two through five were repeated for each of the preselected hearing aids. These tests permitted the aids to be compared in terms of effective gain (the lowest SRTs). Widest dynamic range (the difference between the aided SRTs and the aided TDs), signal-to-noise ratios (tolerating higher levels of noise before discrimination was disrupted) and the relative word discrimination scores. The selection of specific aid was made on the basis of the composite results. Many subjects performed equally well with several of the aids on one or more of the dimensions, but their performance could be differentiated on the basis of other dimensions. When several of the best performing aids gave similar results on several dimensions , the selection was made on the basis of size , weight and esthetic preferences, cost, warranty , repair availability, etc.

Davis et al (1946) reported on the results of a fitting procedure that attempted to complement the audiogram by means of

Selective amplifications and found that it was not an accurate method.

In 1952, Bangs tried a new method of fitting hearing aids to children as young as eighteen months old to determine if they could use a hearing aid efficiently.

In 1952, Glorig concluded that a highly selective procedure was not necessary for the selection of an aid. He further stated that it was not the selection procedure that would produce a good result, but adequate training in its use.

Jeffers (1960) recommended hearing aid selection on the basis of qualitative judgments by the subjects by the subjects. Specifically, it usually consists of asking the patient to listen to a number of hearing aids and to indicate which ones sound best to him. In this way, Jeffers used the quality judgement paired comparison test to assess differences among hearing aids. In order to rule out factors other than differences in acoustic characteristics which might affect the judgments, the subjects were not permitted to see the aids and only conductively deafened individuals whose ears could be presumed to be free of physiological distortion was included. She selected five aids, encompassing a range of good, fair and poor acoustic characteristics and arranged them in four pairs. The 34 conductive hearing loss subjects listened to a 1-minute recording of cold running speech reproduced through a sound-field speaker, first while wearing one aid of a pair and then while wearing the other. The subjects were asked to comment

On their preferences and describe any apparent differences in the aids. The results indicated that the subjects definitely and unambiguously preferred the aids with more desirable acoustic characteristics.

Shore, Bilger and Hirst (1960) found that there are no substantial differences in the performance of patients of patients with different hearing aids on different tone settings, even when there are acoustical differences among the aids themselves.

Zerlin (1962) suggests a method of hearing aid selection which involves the recording of hearing aid outputs onto magnetic tapes. Further, the method of paired comparison is utilized, allowing the listener to compare only two aids at a time. He used this method to evaluate differences among six hearing aids. He taped 30-sec passages of conversational speech in the presence of recorded cafeteria noise, using a 65-dB SPL input for the speech and a 60-dB input for the noise. The 21 sensory-neural hearing loss subjects listened to the recordings through an earphone, and by manipulating a two-position selector switch; they could listen alternately to either one of a pair of aids. Each of the six aids was paired during the recording with every other aid, resulting in 15 recorded pairs. The subjects were asked to rate which aid appeared to make the speech most intelligible. Following the paired comparison test, the subjects were administered a 25-word monosyllabic test list in quiet which had been recorded through the aids in the same manner as the

Conversational speech. His results indicated that the paired comparison preference method produced reliable and definite discriminations among five of the six aids, while the aids could not be differentiated with the WDS results.

In 1963, Resnick and Becker described a procedure in which audiological assessment and counseling of the patient was undertaken by the audiologist, while the actual selection of eh hearing aid is being left to the selected hearing aid dealers. After the patient has been issued an aid he returns to the referring audiologists and receives clinical evaluation of his aid.

Jerger (1967) describes an intermodulation distortion (IDT) for differentiating among hearing aids. He recorded 2 pure tones, one at 1000Hz and the other at 1600Hz, one each channel of a two channel tape-recorder. On one of the channels, the two frequency signal was “clean” on the other channel; it was recorded after being processed through a hearing aid. The subjects listened alternately to the signal pairs under four signal-to-noise conditions. Their task was to determine whether they heard the clean signal or the hearing aid processed signal first. Three hearing aids were used: aid “A” characterized by a flat response and minimal harmonic distortion, aid “B”, by a peaked frequency response and moderate distortion, and aid “C” by considerable harmonic distortion. Performance with these three aids had previously been differentiated with the same subjects using a sentence intelligibility test (PAL-8) in a -6dB signal to competing speech ratio (speech 6dB weaker than noise).

The results indicated that the IDT procedure and the sentence intelligibility tests produced the same rankings among the aids. The signals processed through aid "A" could be differentiated from the clean signal only in the most favorable signal-to-noise conditions; for aid "B", the differentiation clearly occurred at all signal-to-noise ratios, although less so under higher levels of noise; aid "C", on the other hand, could be clearly differentiated from the clean signal at all signal-to-noise ratios.

Although a number of methods for selecting among hearing aids have been suggested, the primary criterion is still the relative score obtained on word discrimination tests. The effectiveness of any such method depends upon the type of speech signal and the condition under which it is utilized. The material must be sufficiently sensitive to reflect electroacoustics differences among hearing aids, and sufficiently reliable so that the error of measurement is less than intelligibility score variations produced by the electroacoustic differences. The most extensive modification relate to the measurement of discrimination against a competing signal, which may be noise or speech.

Studies by Jirsa and Hodgson, 1970; Orchik and Oyer, 1972; Dodds and Bode, 1972; Foust and Gengel, 1973 noted that white small differences could be found when testing under quiet conditions, the tests employing noise interference were able to differentiate the aids much more clearly.

Jerger, Malmquist and Speaks (1966) compared a number of different tests and conditions for their sensitivity in reflecting known differences among three hearing aids i.e., the PAL-s sentences intelligibility test under competing signal conditions, the CID w-22 under quiet condition, the CNC word lists under quiet conditions and PAL PB-50 word lists low pass filtered at 500Hz. The results indicated that only the sentence test clearly distinguished among the aids and that “Performance measures based on single monosyllabic word lists are sufficiently contaminated by error that they do not necessarily reflect meaningful hearing aid performance differences”.

Hood (1970) administers discrimination tests, in quiet and noise, at two or three HTLs (varying somewhat form client to client) roughly representing soft, average and loud conversational speech. He reports a number of instances in which the performance of different aids could not be differentiated at one input level. But could be differentiated at other input levels. Since this method is rather time-consuming, only a limited amount of aids can be evaluated. He points out, however, that he would rather evaluate fewer aids thoroughly than more aids less thoroughly.

Frances P.Harris and Willian R.Hodgson (1974) compared the intelligibility of “hearing-aid-processed” PB lists with aided discrimination under clinical conditions for 15 subjects with sensory-neural loss. They found that the hearing-aid-processed stimuli can be used to simulate actual aided discrimination testing in clinical hearing aid evaluations.

Some investigators have noted the increased information and sensitivity which can be derived from other types of speech signals.

Jerger and Thelin(1968) used the synthetic sentence test coupled with comparing message, in relating electroacoustic characteristics of hearing aids to speech discrimination. These investigators also found that response latency was strongly related to the subject's SSI score, the poorer the score the longer the latency. It is possible that the sensitivity response latency measure in hearing aid evaluations (Hecker, Stevens and Williams 1966).

Monosyllabic word rhyme discrimination tests have been developed and used by various investigators (House, Williams, Hecker and Kryter, 1965; Kreul et al., 1968; Schultz and Schubert, 1969).

Bode and Kasten (1971) used a modified rhyme test to evaluate the effects of hearing aid distortion on consonant discrimination. Their results indicated that the test accurately differentiated among relatively minor increases in distortion. For this reason, and because of the "closed set response format with increased reliability of responses and emphasis on consonantal discrimination," they suggest that the test would be desirable to use in hearing aid evaluations.

Kalikow, Stevens and Elliet (1977) developed a sentence test called SPIN test (Speech Intelligibility in Noise). It tests a listener's ability to utilize both the linguistic situational information contained in sentences with the acoustic phonetic discriminations which must be made to identity low probability words embedded in sentences.

B.Evaluation of the Characteristics of hearing aids:

Several research installations have evidenced an interest in experimental study of the effectiveness of hearing aids.

Among the various characteristics the hearing aids posses the frequency range and distortion forms the major ones which influence the intelligibility of the hearing aid. The frequency range of the hearing aid should be expressed in terms of useful frequency range i.e., frequency area where the gain is sufficient to override the deafness of the subject. A high quality hearing aid would provide a frequency range of at least 3500cps although there will be cases where selective fitting makes it advisable to limit the response to only a part of this rang. Davis found that narrowing the frequency range of a hearing aid to the zone between 1000 and 2000 cps seriously affected the intelligibility score and operating range. He includes that a 300-1000 cps range is ample. 01son (1967) in a study of frequency range performance by normal hearing listeners found that in monaural reproduction speech the normal ear preferred a restricted frequency rang (5000 cps) although the wider frequency range was generally preferred otherwise.

It would seem that although the low frequency range from 250-500 cps is not essential in a hearing aid for intelligibility some response in this range gives a more pleasing tonal quality.

Distortion forms one of the major characteristics of hearing aids. Distortion has been defined as inexact reproduction of a sound wave pattern. Distortion which is present in a hearing aid will affect the output speech intelligibility to a greater extent. Harris (1961), Jerger(1966), Kastein and Lotterman (1967)and Bode (1968) have supplied evidence of decrease in speech intelligibility when excessive distortion products are present in low fidelity circruitory.

Lotternman and Farrer (1965) examined the levels of non-linear distortion present in modern hearing aids and the variability in distortion among instruments of a given model. The magnitude or distortion appeared to be inversely related to the 500, 700 and 900 cps test frequencies, while the frequencies at which maximum distortion occurred was commonly found at higher frequencies for ear level type hearing aids than for body type instruments.

Jerger, Speaks and Malmquist (1966) found both subjective quality judgement and intelligibility to be related to the degree of harmonic distortion present in hearing aids. 36 hard of hearing listeners representing various types and degrees of hearing loss were tested. Using tape recorded speech materials and competing continuous discourse which had been transduced through three hearing aids with harmonic distortion (the average of 500, 700 and 900cps)

Ranging form 4% to 16% they found the performance of normal hearing and hearing impaired to be inversely proportional to harmonic distortion.

Kasten and Letterman (1967) did a longitudinal examination of harmonic distortion in hearing aids. This study examined the harmonic distortion levels of 1170 hearing aids submitted to the veterans administration for contract evaluation during the last six years. Measurements were made is a 75dB SPL input at 500, 700 and 900cps and at the frequency at which maximum distortion was found. The gain of each hearing aid was set with a 62.5dB SPL to that point at which distortion at all amplified frequencies was less than 10%. Based upon average gain and average saturation sound pressure level each aid was placed in one of the three power categories. The results showed that the levels of maximum distortion appeared to be inversely proportional to the rated power of the aids.

Bode and Kasten (1971) made a study on the effect of hearing aid and consonant identification. The experiment was conducted with 34 normal hearing listeners to determine the effects of distortion on consonant identification in noise. Five experimental conditions were employed in which measured harmonic distortion ranged from approximately 1% to 35%. Each listening condition involved playback of recorded test materials at a constant sensation level. Results showed that average consonant identification scores relative to the high fidelity condition decreased 15-20%as a function error scores on the CID sentences and some physical measures of hearing aid performance especially harmonic distortion.

Having said the important characteristics such as frequency range and distortion and its effect on the intelligibility of speech it has been found that the difference in the physical characteristics of hearing aids is more important to some type of hearing impaired listeners than to others and that such individuals will reflect substantial performance difference not readily apparent in large group.

Jerger, Caroln, Malmquist and Speaks (1966) did a study in which a sentence intelligibility test recorded through three hearing aids were presented to 36 subjects with diverse types of hearing loss. Although hearing aids were rank ordered meaningfully on the sentence intelligibility test in inverse proportion to the harmonic distortion, performance difference were not systematically reflected in the monosyllabic word test results. The rank ordering of the aids on PAL-S is identified for every group and the difference among the aids are relatively large. Jerger et al., have concluded although it seem possible to device a behavioral measure that will infact differentiate among hearing aids, one is justified in assuming that such performance difference will necessarily be reflected by monosyllabic word lists as they are currently used in conventional hearing aid selection procedure. However, Jerger concluded that studying of such rank ordering of aids in the presence of competing message is worthy of further study.

Jerger (1967) examined the influence of intermodulation in a ‘non-speech’ procedure. He suggested that such evaluation might be beneficial in detecting differences between aids with widely differing characteristics.

Olsen and Wilber (1967) reported the results of an extensive investigation of the influence of various electroacoustic characteristics. They concluded that the effective bandwidth of the instrument was the only measured characteristics which ranked the aids in the same order as did speech intelligibility.

Raymond Carhart (1964) did a study on speech discrimination with a hearing aid in a competing message situation. He took four groups of 12 subjects each – normal, conductive loss, young adults with sensorineural loss and presbyc usics. They were given unaided and aided tests of monaural discrimination at 30dB SPL in two levels of competing speech. The NU auditory test #2 was employed and conflicting stimuli were emitted from loudspeakers on opposite sides of the subject. In one test condition the primary message originated from the contralateral aids. The experiment was repeated with four comparable groups the only difference being that the gain of the hearing aid and the sound field in which it operated were changed. Results were comparable to an interference function plotted at an earlier date by presenting the NU test #2 to unaided normal listeners and using several levels of competing message. Performance of unaided normal agreed closely with the criterion

Function but it changed in the aided condition about as much as it would have had the competing message been increased approximately 10dB during the unaided condition. Unaided pe rformance of the conductive loss was nearly equal to that of normal, but the change in the aided condition was approximately twice as great. Young sensori-neural loss cases and presbycusis performed essentially equivalently. Both groups showed extra interference unaided which was similar to that exhibited by normal aided and the hearing aid added still more to the interference effect of the competing speech. Moreover in this instance the slope of the interference function was modified no that discrimination had not reached maximum even at very favorable primary to secondary ratio.

Miller and Niemoller (1967) reported reduction in intelligibility as hearing aid microphone was moved away when tested in the presence of noise. They relate this to distortion caused by reflected waves and recommend detachable microphone that can be held close to the talkers lips in order to improve speech to noise ratio.

Jeffers (1960) reported on the relationship between quality judgements and acoustics characteristics.

Witter and Goldstein (1971) made a study on quality judgements hearing aid transuded speech. Frequency range, harmonic distortion, intermodulation distortion and transient measurements were made on five aids which manifested varying amounts on each property. The speech of male and female talkers were recorded through the aids and paired comparison judgements were made by

Thirty normal hearing listeners. It was found that transient response was the best predictor of listeners' judgement and voice may be a factor in the quality judgements task.

Jerger (1971) reports that speech will be affected if there are distortions. He suggests to use hearing aid transduced speech for discrimination so as to select the best hearing aid.

There are very few studies undertaken to evaluate the efficiency and fidelity of various Indian hearing aids.

Pandaley and Murthy (1972) conducted a study on the performance characteristics of Indian hearing aids, namely, Oticon Pushpull, Oticon popular, Oticon super 350, Oticon Extra Super, Danavox Economy 647-I, Danavox AVC, VH 200 Rionet H536 and L.P.T. hearing aid. They reported that the Indian hearing aids differ very much in terms of distortion characteristics. It is also reported that most of the Indian hearing aids produced more than 5% distortion which can therefore affect speech.

G.Ramani (1975) made a study on quality of hearing aid transduced speech discrimination. The purpose of the study was to evaluate the efficiency and fidelity of various Indian hearing aids using hearing aid transduced monosyllables for discrimination. In this way , the quality of the Indian hearing aids viz., Oticon Extra Super, Danavox AVC, Oticon Super Danavox 6471 and Rionet were selected. 100 subjects were selected for the study. The

Subjects were first presented with the recorded speech materials so as to obtain both the SRT and speech discrimination scores. They were then presented with the hearing aid transduced monosyllabic words at 35dB SRT. The difference in the discrimination score between unaided and aided conditions was taken to assess the performance difference among the hearing aids. It was found that the hearing aids differ in performance depending on their physical character. The hearing aids could also be rank ordered based on their performance.

25 subjects were also tested for the aided discrimination in the presence of a competing signal. Three signal-to-noise ratio, at 0dB S/N, at -5dB S/N and at -10dB S/N were used. The discrimination of the subjects with the hearing aid in quiet and in the presence of noise were compared. It was found that the hearing aids could be further differentiated when they were made to perform under difficult situations like the performance in the presence of a competing noise.

G. Ramani (1975) thereby suggested of this procedure as an alternative to the conventional hearing aid evaluation procedure for the selection of the hearing aid.

Lalitha (1979) made a study on the electroacoustic characteristics of Indian hearing aids and their suitability to fifty hard-of hearing individuals. 11 hearing aids were used, namely, Arphi universal, Arphi Super, Arphi Extra Super, BEL VH 200, Oticon popular, Oticon push pull , Oticon super, Oticon Extra super , Rionet , Deluxe HA20, Trip II Super Silicon with receiver 187-57-7 and Trip II Super Silicon with receiver 57-07. The electroacoustic characteristics measured for these hearing aids were gain, peak gain, HAIC gain, frequency range, MPO, maximum output at 1KHz, Maximum HAIC output and Harmonic Distortion. Her findings were:

1. The manufacturers specifications about the performance characteristics of the hearing aids are not available most of the times and whatever were available did not simulate the results obtained in this study.

2. The gains of the hearing aids are most of the times not adequate to provide sufficient amplification for most of the patients.

3. The tone control switch did not perform its function for which it was designed to and claimed by manufacturers.

4. The distortions are found to be more, which affects the intelligibility of speech.

5. Fifteen out of fifty subjects, to be more, specific, 22 ears out of 100, were found to be the candidates for the selection of one or more hearing aids out of the II available Indian hearing aids.

For the maximum utilization of the auditory potential of the hard-of hearing child it is imperative that the hearing aid functions optimally. A hearing aid can mean the difference between adequate or poor reception of auditory signals. Educational delay often results from partially received or distortion of auditory messages (Zink, 1972). The development of a meaningful standard method for measurement and reporting distortion levels in hearing aid should be a primary goal of both audiologist and hearing aid manufacturer. Such a standard should reflect distortions under conditions approximating those in which the hearing aid may be expected to operate and should likewise permit interpretation of

Distortion data by those engaged in the evaluation of hearing instruments.

The aim of the present study is, therefore, to apply the intermodulation distortion test procedure clinically for differentiating among the Indian hearing aids. Since only very few studies have been made on Indian hearing aids and practically nothing on their intermodulation distortion pertaining to this line of thought the present study was undertaken. If the hearing aid evaluation in done through this means, then the problem of stocking all the aids in a clinic can be eliminated. It also helps the clinician to select the proper hearing aid/s for trail. For the manufacturers, this test would prove useful as the Indian hearing aids have not been subjected to this kind of test.

C H A P T E R – III

METHODOLOGY

The methodology of the present study is described under the following headings.

1) Procedure for recording ‘clean’ signal
2) Procedure for recording hearing-aid processed signal.
3) Procedure for finding intermodulation distortion.

I. Procedure for recording ‘clean’ signal:

The following instruments were used for the recording of the ‘clean’ signal,

1) Audio Oscillator, Radart type 926-B
2) Beat Frequency Oscillator, B& K type 1022
3) Solid state Pre-amplifier, Phonica model SE-5X.
4) Sonnet Stereo Tape-recorder.

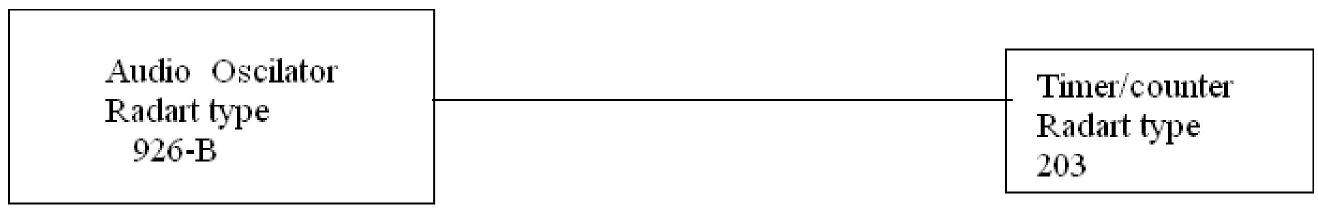
Prior to the recording of the ‘clean’ signal, the puretone signals (1000Hz and 1600Hz) were calibrated using a Timer/counter (Radart Type 203).

Block diagrams I and II indicate the arrangement of the instruments for the calibration of the puretone signals (1000Hz and 1600Hz).

The two pure tones were then recorded on one of the channels (left) of two-channel sonnet stereo tap-recorder. The intensity of the recording was held constant with the help of the VU meter.

The ‘clean’ signal was tape-recorder at the Electronics Laboratory, A.I.I.S.H. Recording was repeated until it met satisfaction. This consensus approval was available only on the fourth attempt.

Block Diagram I



ARRANGEMENT OF THE INTRUMENTS USED FOR THE CALIBRATION OF THE 1000Hz TONE

Block Diagram-II

ARRANGEMENT OF THE INSTRUMENTS USED FOR THE CALIBRATION OF THE 1600Hz TONE

Block diagram II indicates the arrangement of the instruments used for the recording of the 'clean' signal.

II. Procedure for recording hearing aid processed signal:

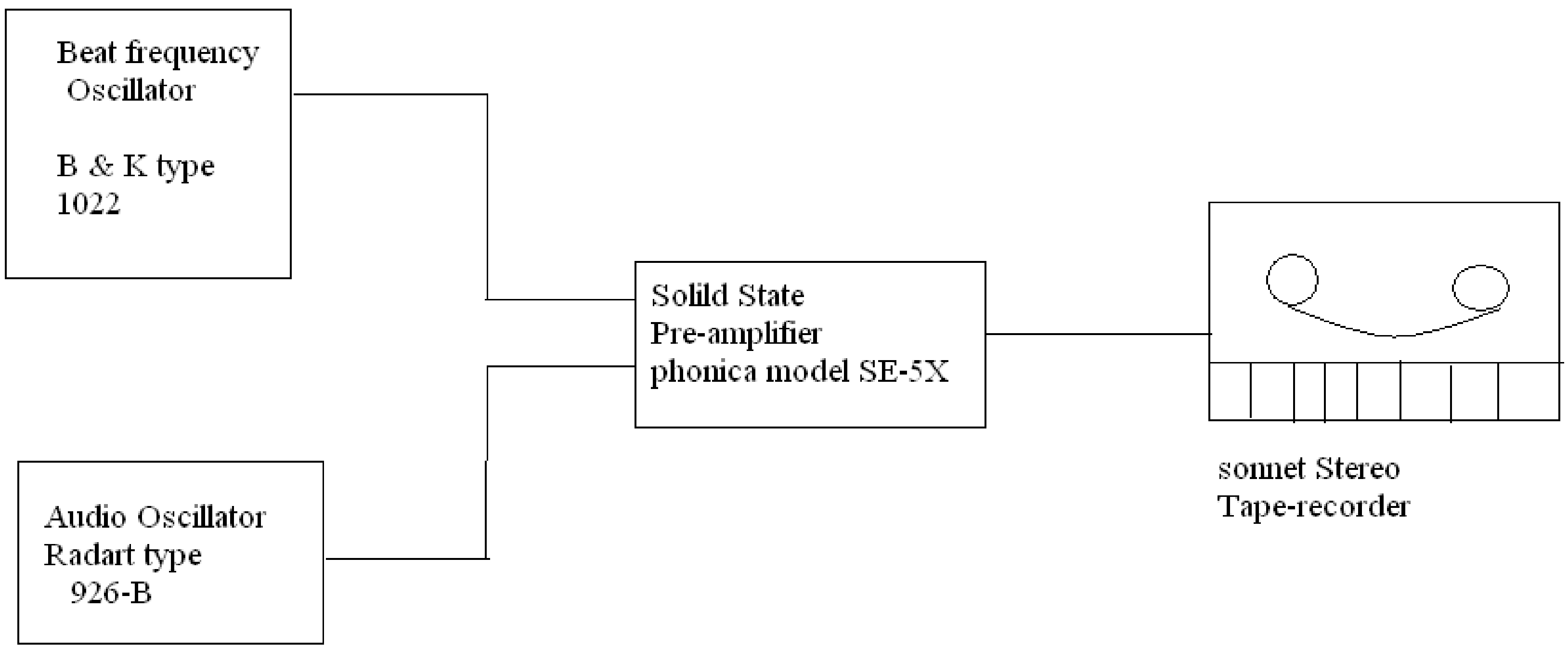
The following equipment were used for the recording of the hearing aid processed signal.

1) Audio Oscillator, Radart Type 926-B
2) Beat Frequency Oscillator, B & K type 1022
3) Solid state pre-amplifier, Phonica Model SE-5X
4) Hearing aid Test Box, B & K type 4217
5) Precision sound Level Meter, B & K Type 2203
6) Octave Filter Set, B & K type 1613
7) 2 c.c. Coupler Type DB 0138
8) Condenser microphone type 4144, NO.280896
9) Sonnet Stereo Tape-Recorder
10) 5 Hearing aids
    a. Arphi super ….(PS_1)
    b. Arphi Extra super (PS_2)
    c. Arphi Universal (PS_3)
    d. Elkon 6903……… (PS_4)
    e. Rionet H536………(PS_5)

The two pure tones, 1000Hz and 1600Hz were recorded on the other channel (Right) of the tape-recorder, after being processed through a hearing aid. For all the hearing aids, the gain was set at '5', tone control setting at 'N' position and the input to the hearing aid was kept constant at 100dB SPL. The intensity of the recording was kept constant with the help of the VU meter. Each hearing aid processed signal was recorded for three minutes with a time interval of 30 seconds between each recording.

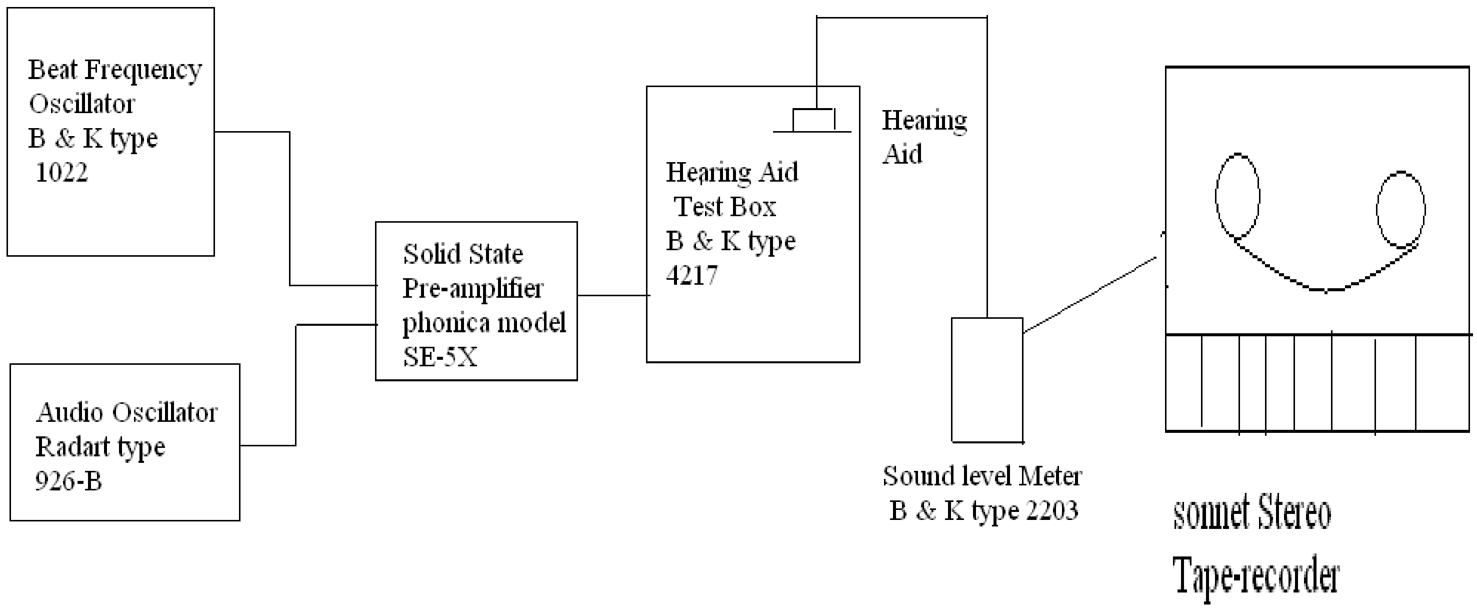
Block diagram IV indicates the arrangements of the instruments

Block Diagram- III



ARRANGEMENT OF THE INSTRUMENTS USED FOR THE RECORDING OF THE ‘CLEAN’ SIGNAL

Block Diagram- IV



Used for the recording of the hearing aid processed signal.

III. Procedure for finding intermodulation distortion

a. Testing environment,

The test was carried out in a sound treated audiometric room at the audiology Department; A.I.I.S.H. Testing was done in a two-room situation.

b. Subjects:

15 normal hearing subjects were selected randomly from the student population of the Institute. The age of the subjects ranged from 18 to 22 years. Both males and females were included for the study.

c. Instruments:

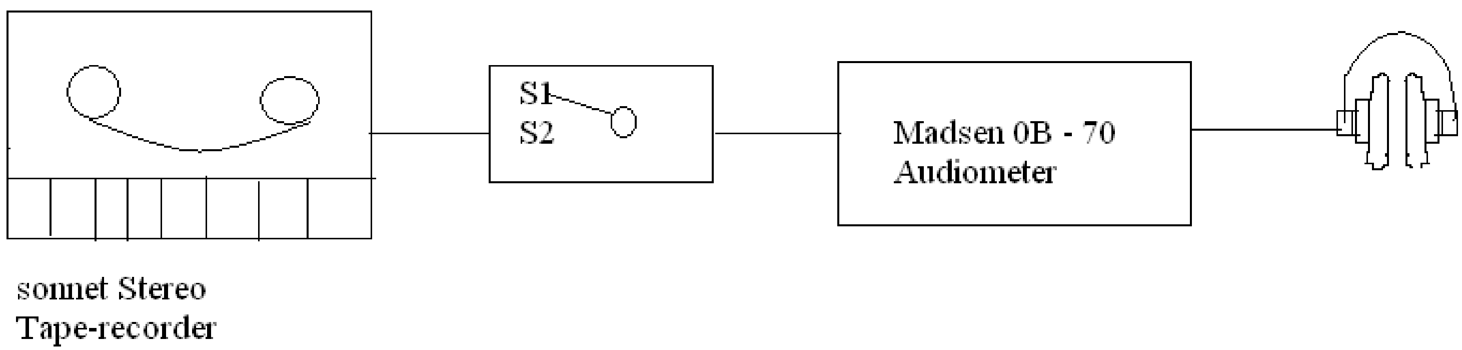
The following instruments were used for finding the performance of normals on the intermodulation distortion test:

1) A Madsen 0B-70 Audiometer
2) A Sonnet Stereo Tape-recorder
3) A two-position selector switch.

Block diagram V shows the set up of the instruments during the testing procedure.

The Madsen 0B – 70 audiometers was used for feeding the taped signals into the subject's ears via a two-position selector switch, whereby the two taped signals could be presented alternately. One position on the selector switch was indicated by S_1 for the hearing aid processed signals and the other position was indicated by S_2 for the 'clean' signal.

Block Diagram – V



Set-up of the Instruments During the testing Procedure

The head-set was TDH 39 with cushion LX 41/AR. The first channel of the audiometer was used for the taped signals and the second channel was used for the narrow band noise. The output of the signal was controlled by the intensity dial for channel I.

Block diagram VI shows the functions of the Madsen 0B -70 audiometer.

Block diagram VII shows the settings of the Madsen 0B-70 audiometer during the testing procedure.

d. Testing Procedures:

i) Instructions: for testing the normal hearing subjects, the following instructions were given:

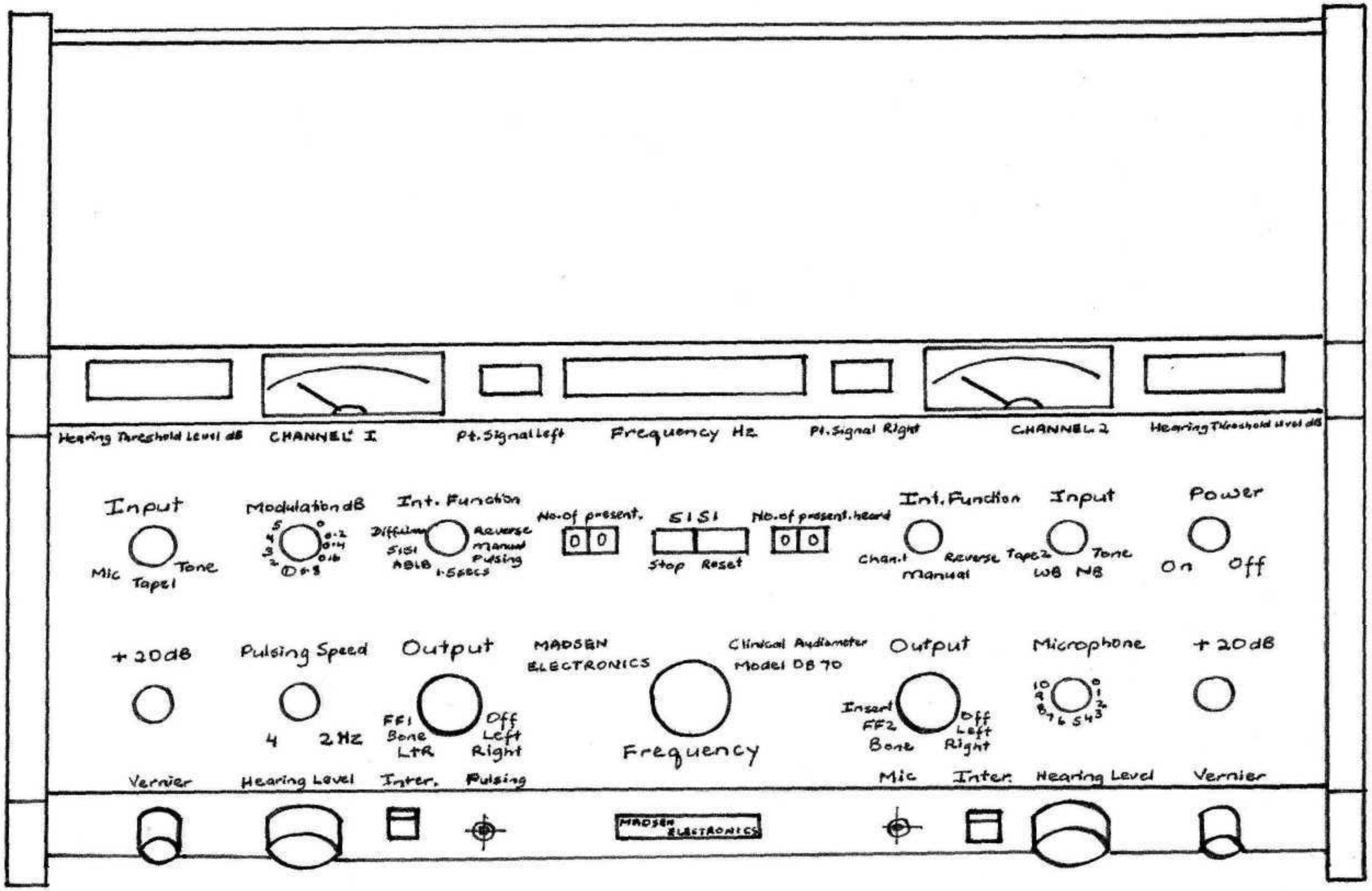
> "You will be hearing the signals alternately in the presence of noise. After hearing, you are required to indicate whether the signals heard in presence of noise were the same or different".

ii) Level of presentation: The signal was presented at nearly comfortable level of the subjects. The noise level, in the same earphone, was raised until the signal was just detectable.

iii) Test Paradigm: A test paradigm (as shown in Appendix II) was used. The subjects listened to the 'clean' signal and the hearing aid processed signal under one noise condition.

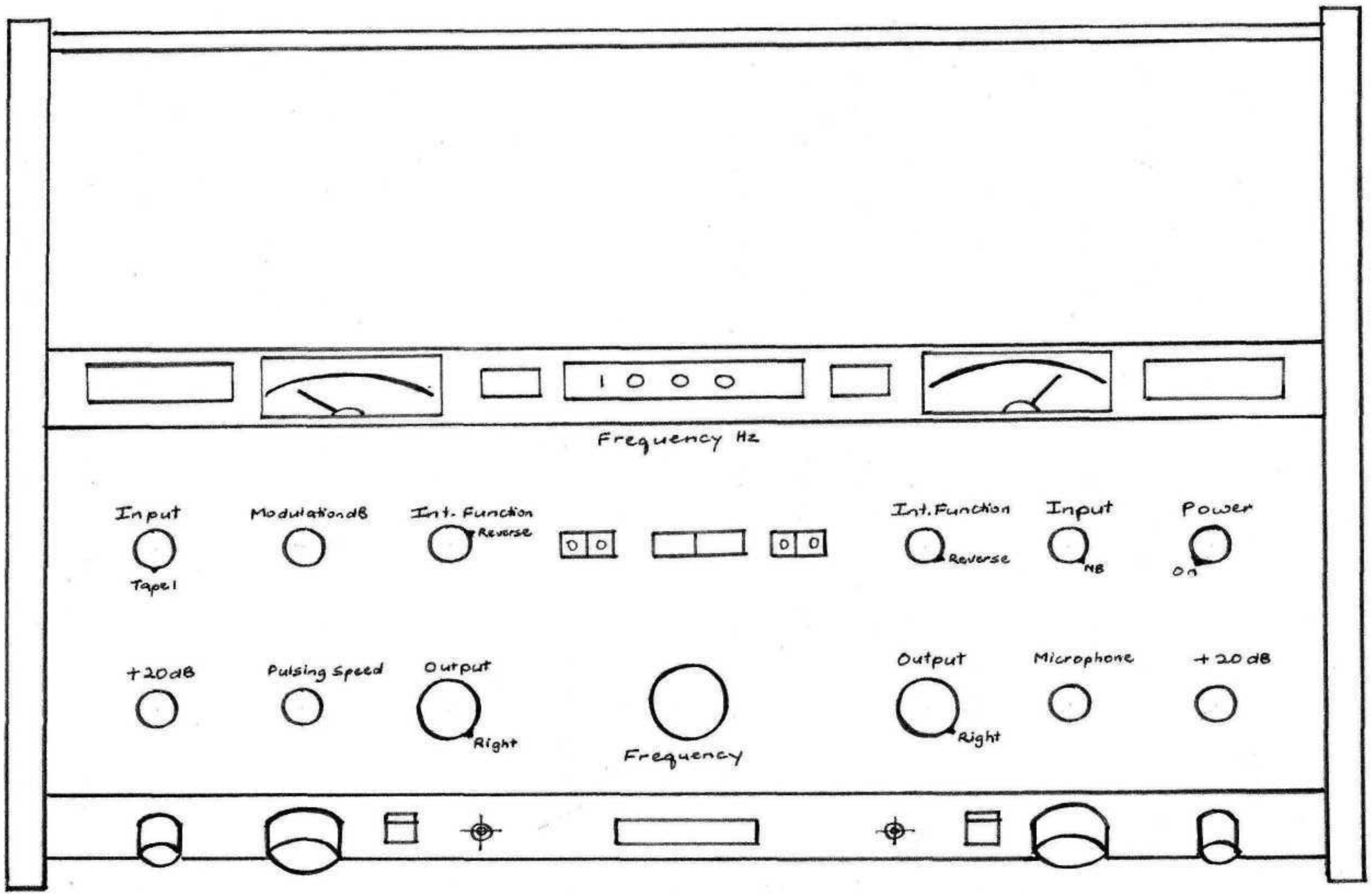
2 trials were given to each hearing aid processed signal- as test re-test reliability measures for the subject. Controls were also used to check the reliability of the subject's performance on the test.

BLOCK DIAGRAM VI



FUNCTIONS OF THE MADSEN DB 70 AUDIOMETER

BLOCK DIAGRAM VII



SETTINGS OF THE MADSEN OB 70 AUDIOMETER DURING THE

C H A P T E R– IV

RESULTS AND DISDUSSION

The performance of hearing aids depends upon the amount of distortions, frequency response, gain, etc. Among these factors the important character that affects speech reproduction is the distortion. Leterman (1967) have supplied evidence of decrease in speech intelligibility when excessive distortion products are present in the hearing aid. When the distortion is higher, the intelligibility of speech is affected to a great extent. Recently Jerger, Speaks and Malmquist (1966) found both subjective quality judgements and intelligibility to be related to the degree of harmonic distortion present in hearing aids.

The aim of the study was to apply the intermodulation distortion test (IDE)procedure clinically so as to differentiate among the Indian hearing aids. In this way, it is possible to find out whether the Indian hearing aids produced intermodulation distortion.

The results and analysis of the performance of normals on the IDT (as shown in Table No.1) revealed that there was a significant difference between the 'clean' signal and the hearing aid processed signal.

All the subjects reported intermodulation distortion on all the hearing aids tested, when Narrow Band noise was used as the competing signal. Further, it was also observed that when 2 subjects were tested using white noise as the competing signal, the subject indicated that the 'clean' signal and hearing aid.

Table No. I

Trials	I	II	1	2	3	4	5	6	7	8
(1)	C	PS_1	diff	Diff	Diff	Diff	Diff	Diff	Diff	Diff
(2)	C	PS_1	diff	diff	diff	diff	diff	diff	diff	Same
(3)	PS_2	C	diff	diff	diff	diff	diff	diff	diff	Diff
Control	PS_2	PS_2	Same	Same	Same	Same	Same	Same	Same	Same
(4)	PS_2	diff	diff	diff	diff	diff	diff	diff	diff	Diff
(5)	PS_2	C	Diff	Diff	Diff	Diff	Diff	Diff	Diff	Same
(6)	C	PS_3	diff	diff	Same	diff	diff	diff	Same	Same
Control	C	C	Same	Same	Same	Same	Same	Same	Same	Same
(7)	C	PS_4	Diff	Diff	Diff	Diff	Diff	Diff	Diff	Diff
(8)	PS_4	C	Diff	diff	diff	diff	diff	diff	diff	diff
(9)	C	PS_5	Diff	Diff	Diff	Diff	Diff	Diff	Diff	Same
(10)	PS_5	C	Diff	diff	diff	diff	diff	diff	diff	Same

Note: 'C' indicates 'clean' signal.

******contd.

Table No. I (contd.)

Trials	I	II	9	10	11	12	13	14	15	% of Subjects indicating difference between the two signals
(1)	C	PS_1	diff	Diff	Diff	Diff	Diff	Diff	Diff	100%
(2)	C	PS_1	diff	diff	diff	diff	diff	diff	diff	
(3)	PS_2	C	diff	diff	diff	diff	diff	diff	diff	100%
Control	PS_2	PS_2	same	same	same	same	same	same	same	
(4)	PS_2	C	diff	diff	diff	diff	diff	diff	diff	100%
(5)	PS_2	C	diff	Diff	Diff	Diff	Diff	Diff	Diff	
(6)	C	PS_3	diff	diff	diff	diff	diff	diff	diff	
Control	C	C	same	same	same	same	same	same	same	
(7)	C	PS_4	diff	Diff	Diff	Diff	Diff	Diff	Diff	100%
(8)	PS_4	C	diff	diff	diff	diff	diff	diff	diff	
(9)	C	PS_5	diff	Diff	Diff	diff	Diff	Diff	Diff	100%
(10)	PS_5	C	diff	diff	diff	same	diff	diff	diff	

Note : 'C' indicates 'clean' signal.

Processed signal were different.

A special case of Binomial test was applied to find the difference statistically. The statistical analysis is as shown in Page No. Hence, the hypothesis that there exists no difference between the 'clean' and the hearing aid processed signals has been rejected indicating that there is difference in performance among the hearing aids in terms of intermodulation distortion.

Since the results indicated that all the available Indian hearing aids tested showed intermodulation distortion. It would be ideal if all the manufacturers of Indian hearing aids could subject their hearing aids to this kind of test.

Hence, the intermodulation distortion test appears to merit consideration as a measure for differentiating among hearing aids.

Statistical Analysis

Q : Is there a difference? Yes or No

P (Yes) = P = I- P (No)

Ho : there is no difference or P =0

X= the NO. of 'yes' answers

$P(X=K) = (K^n)\ P^k\ (1-P)^{n-k}$ K=0, 1, …………n.

Under Ho P (X=0)=1

The best test for testing the hypothesis accepts it when X=0 and reject it otherwise. In the Present Case, we reject Ho Since X=15=n.

CHAPTER-V

Summary and Conclusions

Understanding the fact that there are various hearing aid selection procedures, the present study was undertaken to apply one such procedure-the present study was undertaken to apply one such procedure-the intermodulation distortion test (IDT). The test was used clinically to differentiate among the Indian hearing aids. This would then reflect meaningful hearing aid performance differences thereby enabling a clinician to select the proper hearing aids for trial.

This information would also be useful to the manufacturers of the Indian hearing aids as the Indian hearing aids have not been subjected to this kind of test.

For this purpose, 2 puretone , one at 1000Hz and the other at 1600Hz, were recorded on each channel of a two-channel tap-recorder. On one of the channels, the signal was 'clean' and on the other channel the signal was a hearing aid processed one, under a constant tone control setting, gain and output level.

The subjects were made to listen alternately to the signal pairs under just one noise condition. Their task was to determine whether they perceived the signal quality between the 'clean' signal and the hearing aid processed signal as the same or different.

Available clinic hearing aids were used, namely,

1) Arphi Super
2) Arphi Extra Super
3) Arphi Universal
4) Elkon 6903
5) Rionet H536

The results were statistically analyzed and the following conclusions were drawn:

Conclusions:

1) There is a significant difference between the ‘clean’ signal and the hearing aid processed signal.

2) All the subjects report intermodulation distortion on all the Indian hearing aids tested.

3) The intermodulation distortion test appears to merit consideration as a measure for differentiating among hearing aids in hearing aid selection procedures.

Recommendations :

1) The study could repeated with other available Indian hearing aids.

2) The procedure could be extended to sample an aid’s performance under different tone control settings, gain and input levels, in the presence of different competing messages at various signal-to-noise ratios.

3) The manufacturers could subject the Indian hearing aids to this test so as to improve their aids in terms of their performances.

4) Standard test procedures could be developed in the same lines of the present study for different clinics to evaluate the Indian hearing aids available.

BIBLIOGRAPHY

1. American Speech and Hearing Association. Conference Hearing Aid Evaluation procedures on ASHA reports No. 2 , 1967.

2. Carhart, R. - "tests for selection hearing aids" laryngoscope , 56, 1946, 780-794.

3. Flottorp, G. - "Intermodulation in hearing aids" Scandinavian Audiology, Supplement 1, 1971,63-67.

4. Harris F.P.& Hodgson W.R.- "Use of hearing-aid-processed stimuli is hearing aid evaluation" Audiology Vol.13, No.6, 1974, 490-494.

5. Jeffers, J. - "Quality Judgement in hearing aid selection" JSHD 25, 1960, 256-266.

6. Jeffers, J.& Curtis R.Swith - "On hearing aid selection – in part a reply to Resnick and Becker." ASHA, 6, 1964, 504-506

7. Lalitha - "A study of Electroacoustic characteristics of Indian hearing aids and their suitability to fifty hard-of-hearing individuals". M.Sc. Independent Project, Mysore University.

8. Mark Ross - "Hearing aid evaluation" chapter 33, 624-642 in "Handbook of clinical audiology" by Jack Katz. The Williams & Wilkins Co., Baltimore, U.S.A.(1972).

9. Mayadevi - "The Development and Standardization of common speech discrimination test for Indian", M.Sc. Dissertation, Mysore University (1974).

10. Pandalay & Murthy - "Performance characteristics of Indian Hearing aids." A.I.I.S.H. Journal, Vol.III, 1972, 108.

11. Ramani G. - "Quality judgements of Indian Hearing aids using hearing aid transduced speech discrimination". M.Sc. Dissertation, Mysore University (1975).

12. Zerlin S. - "A new approach to hearing aid selection". JSHR, 5, 1962, 370-376.

13. Zink,G.D.& Alpiner, J.G. - "Hearing Aids one aspect of a state public school hearing conservation program". JSHD, 33, 1968, 320-344.

APPENDIX – I

AUDIO OSCILLATOR BADART TYPE 926-B:

The Audio Frequency Oscillator has been designed to give extremely wide coverage of lower frequency signals. It completely covers the audio frequency range, between the limits of 15c/s to 50,000c/s with low distortion and level output over the full range.

The frequency coverage is achieved, by using a bridge-type resistance capacity oscillator with three switched ranges. It incorporates stabilizing circuit and is followed by 2 stages of amplification with a heavy negative feedback. This maintains stability of frequency and output voltage level with negligible distortion. A useful feature is the inclusion of an optimal square wave output.

The instrument has been packed ready for operation from 230V, 50c/s AC. The range of frequencies from 15c/s to 50Kc/s is covered in three ranges marked A,B and C as given bellow:

Range A: - 15 – 300 c/s

Range B: - 300 – 4000 c/s

Range C: -4 – 50Kc/s .

BEAT FREQUENCY OSCILLATOR B & K TYPE 1022:

The beat frequency Oscillator B & K type 1022 is a precision signal generator. It covers a frequency range from 20 to 20KHz and is designed for acoustical, vibrational and electrical measurements. The output attenuator has a range of 100 dB in 10dB steps and the output impedance can be varied to give maximum power. It is basically a wide range measuring amplifier for and peak rectifier circuits. A display meter with interchangeable meter scales on which the range setting to automatically indicated facilitates the direct calibration of the 2607 for SPL., Acceleration and voltage measurements.

amongst other features are mains or battery operation, overload indicator on input and output sections. The instrument also contains frequency weighting networks A, B and C as well as the D network.

SONNET STEREO TAPE-RECORDER.

The sonnet stereo tap-recorder is a delicate instrument that requires proper handling to give the prolonged continuous and satisfactory results. It has a frequency response of 30Hz to 14 Hz. Amongst other features are mains operation (220V AC at 50 c/s), internal speakers, external speakers, recording/reproduction and erase heads. The tape-recorder employs a four track system which can be used for either stereo or monaural recording as well as playback. There are various switches and controls – volume control (left, right), Recording switch (left, right,) Bass control, Treble control, Power ON/OFF, Speaker ON/OFF, pause control, etc.,

TIMER/COUNTER RADART TYPE 203:

The time counter type 203 is a general purpose electronic counter based on solid state techniques. An important feature of the instrument is its high noise rejection which ensures immunity from noisy environments. The sensitivity control can be adjusted to select the correct trigger point. An input voltage protection circuit is incorporated for the front panel input and external clock input channels. The maximum safe input which can be applied is 300V r.m.s. at 50Hz for the front panel input and 100V r.m .s. at 50Hz for the external clock input. Range selection and function selection are by rotary switches. Where a resolution in excess of full scale is required, the instrument can be used in the over range condition. This is indicated by a front panel over range lamp. The 203 Timer/counter can be operated in four modes which are selected by the front panel "FUNCTION" switch. The four modes include the Frequency Mode, Period Mode, Time Mode and Count Mode. The instrument operates at 230V AC.

HEARING AID TEST BOX B & K TYPE 4217:

The hearing aid test box B & K type 4217 consists of a miniature anechoic enclosure with a built-in loudspeaker and a transistorized oscillator and amplifier section.

For more information, B &K Manuals may be refered.

PRECISION SOUND LEVEL METER B & K TYPE 2203:

The SPL meter type 2203 is an instrument designed for outdoor use as well as for precise laboratory measurement. It is portable and battery driven. This is usually used in conjunction with a suitable filter set, e.g., the B & K Octave filter set type 1613. The B & K type 2203 covers the range 18 to 134 dB. This covers most sound levels which need to be measured. All three weighting networks (A, B and C)are included in the instrument as well as a linear characteristics and means for connecting external filter circuits for further shaping of the frequency characteristics if necessary.

The instrument can be divided into the following man parts:

1. Condenser microphone and source follower.
2. Input amplifier with input attenuator.
3. Weighting networks.
4. Output amplifiers with output attenuators
5. Meter rectifier and indicating meter.
6. Power supply.

THE OCTAVE FILTER SET TYPE 1613:

The octave filter set is a compact, portable unit containing II band-pass filters for octave analysis. It is primarily designed for use in conjunction with the precision sound level meter type 2203, the combination being a portable noise and vibration analyzer. Only 4 screus are used for joining the units together and the electrical connection is provided by a connection bar.

APPENDIX - II : TEST PARADIGM

Trials	I	II	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	% of Subjects indicating difference between the two signals
(1) (2)	C C	PS_1 PS_1		
(3)	PS_2	C		
Control	PS_2	PS_2		
(4)	PS_2	C		
(5) (6) Control	PS_2 C C	C PS_3 C		
(7) (8)	C PS_4	PS_4 C		
(9) (10)	C PS_5	PS_5 C		