HIGH FREQUINCY AUDIGMETRY -
A REVIEW 1966-1996

Reg: No. M9810

Independent Project submitted as a part fulfillment for the First Year M.Sc, (Speech and Hearing) to the University of Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MYSORE - 570 006

Dedication to my dearest

Achan and Amma

who are my first teachers, for they have helped me to climb the ladder of knowledge. You are my power and inspiration behind all my successes which I have achieved in my life. It is with your love and your confidence in me I have reached this place.

AND

To all my

Teachers

Who laid the foundation of this field into me.

MYSORE - 570 006.

CERTIFICATE

This is to certify that this Independent Project entitled ***"High frequency Audiometry, A Review -1988-1998"*** **is a bonafide work** in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with *Register No. M9810.*

Place : Mysore
Date : May 1999

Dr. (Miss) S. NIKAM
Director All India Institute of Speech and Hearing,
Mysore - 570 006.

CERTIFICATE

This is to certify that this Independent Project entitled *"High Frequency Audiometry, A Review 1988-1998"* has been prepared under my supervision and guidance.

Place: Mysore
Date : May 1990

Dr. K. Rajalakshmi
Lecturer in Audiology
All India Institute of Speech and Hearing.
Mysore - 570 006.

DECLARATION

This Independent Project entitled *"High Frequency Audiometry - A Review 1988-1998"* is the result of my own study under the guidance of **Dr.(Mrs) K.Rajalakshmi,** Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

Place : Mysore

Date : May 1999

Reg. No.M9810

ACKNOWLEDGMENTS

I extend my sincere and heartfelt gratitude to my teacher and guide; Dr. K. RAJALAKSHMI, for her valuable guidance throughout this project "Ma'm, thank you very much, for all the guidance and help you had provided me. Without your help I would not have been able to successfully accomplish this work of mine".

I take this opportunity to thank Dr. S. NIKAM, Director, AIISH, Mysore, for permitting me to carry out this project

Achan and Amma, your love, support; understanding, prayers and blessings has made me to stand where I am now. Your confidence in me is a real boost up for me. I love you both.

A special mention to all my 3 loving uncles with whose love, support and encouragement, I was able to achieve many things in life. "Dear Raghu maman, Sasi maman and Vijayan maman, there are no words to express my gratitude and love to you. Thank you very much for everything you have given me".

My dear Ammooma, Its from you, that I have learnt a lot of things about life. I love you so much.

Dear Uma aunty, Rema aunty, Sreeja aunty and all my cousins, thank you for all the help you had done for me, especially during my stay in Chennai for my B.Sc.

I thank all the staff at SRMC and RI for their valuable support and guidance, they had provided me even after I have graduated from there. "Thank you very much Roopa ma'am, Akila ma'am, Vadi ma'am, Suneeta ma'am, Raji ma'am and Nappi ma'am.

I extend my sincere gratitude to Dr. Rangasayee, Dr. Rajashekhar and Dr. K. Lakshman, for their valuable advice which they had given me.

I also express my sincere gratitude to all the staff at AIISH, for their guidance and encouragement they had provided me.

Sheny, Liji, Sneha, Betcy and Nithya through you people are far away from me, your love and timely contacts are a source of inspiration for me.

Amirtha, the times which I had spent with you are wonderful and memorable. They were the real times of enjoyment which I had and your friendship with me is a life time treasure.

Vasanti, 4 years with you, I have so much of good and bad memories to share with you. Thank you, for being a good friend of mine.

Akila, thank you very much for all the help you have done, especially during this project work, in collecting data.

Uma Bharati, your bla — bla — mouth always kept me out of tension. I like your frankness. Also I thank you very much for your helping hand during this project work.

My roomie, Sandhya, thanks for tolerating me throughout the year and also for the troubles Thave given you. You're a great room-mate.

My heartful gratitude to all my class mates for their help and guidance, especially Sapna, who gave me real moral support, whenever I used to feel depressed in this new place. 'Thanks a lot my dear J.C partner'.

Last, but not the least, I take this opportunity to thank MARUTHI COMPUTERS and Soft Touch Computers for their excellent typing. A special mention to Mr. Venu and Miss Rathna, for their magic fingers. *"Mr. Venu,* your patience and your excellent job is one of the assets of this project".

CONTENTS

HIGH FREQUENCY AUDIOMETRY - A REVIEW (1988-98)

INTRODUCTION

High-frequency audiometry refers to threshold testing of frequency above 8000Hz. It is a procedure which can be used with either air-conduction or bone conduction to test frequencies from 8000Hz to 20,000Hz and 16000 Hz respectively. Wegel (1932) first reported that the total frequency response of the human ear to be approximately 16 Hz to 24,000Hz

Studies about the sensitivity at signal frequencies above 8kHz have both diagnostic and rehabilitative value. (Fausti et al 1979 b, Berlin 1982, Fausti and Rappaport 1985) The perception of high frequencies is very subjective and this could be the cause of possible errors during testing.

The evaluation of the hearing function for frequencies above 8kHz refers to the application of various normative thresholds related to each age group owing to the considerable threshold for the high frequency range. However, recent studies have brought to light the importance of this method.

Both ANSI and ISO have established groups to look at high-frequency audiometry both in terms of test equipment and in terms of possible normative data. The specific test procedure to be used varies with instrumentation. In one case a probe tube is placed down the canal, in another high fidelity circumaural earphones are used. In the third approach a large bone vibrator is used to transduce the signal. Yet there are no standards for these procedures.

There are commercially available audiometers for testing this frequency range, such as Monitor/Demlar Model 20k extended high - frequency audiometer.

Specialized equipment and unique calibration procedures are required for high-frequency audiometry. Once these hard ware requirements are met, signals transduced under MX - 48/AR cushions by wide response earphones have produced reliable audibility thresholds upto 20kHz using standard manual techniques in children (Zislis & Fletcher 1966, Harris and Ward 1967) and adults (Beiter and Rupp 1972, Beiter and Talley 1976 ; Fausti et al 1979 a) Acceptable reliability has also been reported using automatic tracking under earphones (Fletcher 1965, Harris and Myers 1971 ; Northern et al 1972) and by conventional testing in sound field (Osterhammel 1978) Myers and Harris (1970) compared threshold reliability in seven systems encompassing both sound field and earphone presentation of tones and noise. They concluded that each of the techniques yielded reliable data.

Fausti et al (1982) constructed release - from - masking frequencies for frequencies between 8 kHz and 14 kHz in normal ears. The finding suggested that the listeners were not responding to distortion products involving the lower frequencies, but were validly perceiving high frequency stimuli.

Various investigators (Frank and Ragland, 1987 ; Gauz and Smith 1987, Green, Kidd & Stevens 1987, Otstad, Laukli and Mair 1988, Stelmachowicz, Beuchaine, Kalberer, Langer and Jesteadt, 1988) have studied the variability of the air and bone systems and found them to be comparable in variability to other systems, with only some what larger standard deviations in the higher frequencies. There also have been some attempts to establish normative threshold data for high-frequency test procedures.

Threshold audiometry at frequencies above 8kHz is instrumentally feasible, clinically reliable, and appears to be a valid indication of auditory sensitivity. The increased knowledge gained by expanding the test frequency range in threshold audiometry may be significant and deserves further exploration.

Clinical application of high-frequency audiometry:

Zeslin and Fletcher (1966) imply that if intense acoustic stimulation first affects the high frequency hearing, perhaps the detection of a hearing loss at high frequencies can prevent further hearing loss at more important (lower) frequencies by indicating the need to change the individual's sound environment.

High-frequency audiometry purportedly can reveal sensorineural hearing losses related to ototoxicity (Dreschler, vander Hulst, Tange and Urbanus 1985, Goldstein, Shulman and Kisiel 1987, Rappaport, Fausti, Schechter and Frey 1986, Vander Hulst, Dreschler and Urbanus 1988), to noise exposure (Gauz, Smith and Hinkle, 1986; Goldstein et al, 1987, Rahko and Karma 1986), before the hearing loss is evident in frequencies at or below 8000Hz.

- Differentiation between noise induced hearing impairment and other high-frequency sensori-neural hearing impairment such as presbycusis (Laukli and Mair 1985)

- Studies have shown the selective or early involvements of high -frequency hearing in certain auditory and extra auditory pathologies; Rosen and Olen (1965) in peripheral vascular disease; Cunningham and Goetsinger (1974) in patients with hyperlipemia. Studies have shown relationship between high-frequency thresholds and industrial noise (Sataloff et al (1967), Robertson and Williams (1975), Osterhammel (1979), Dieroff (1982), Luts (1982), Filipo and Deseta (1983).

- Cunningham et al (1983), found a relatively lower threshold for high-frequencies in smokers, which was not statistically significant.

- To measure the speech recognition ability in persons with significant hearing impairments, at the routine audiometric frequencies with good speech intelligibility and articulation (Berlin 1982)

- High"frequency hearing loss has also been correlated with otosclerosis, hereditary sensori-neural hearing loss and Meniere's disease (Osterhammel, 1980)

Drawbacks of high-frequency audiometry

1. Most sounds occurring in everyday life (for eg:- speech) fall within the range of 125 Hzto 8kHz.

2. Normative threshold data till 8000Hz are less affected by difficult to control acoustic factors of the puretone signals. This is one of the reasons,

for which the standard puretone audiometric test battery generally uses lower octave frequencies from 250 Hz to 8 kHz.

3. The use of high-frequency puretones in hearing testing was found to be plagued by difficulties in accurate assessment due to the acoustic characteristics of the high-frequency pure tone itself [(i.e.) short wave length, thus causing standing waves] and psycho-physical problems such as physiological noise, and problems in recognition of the puretone.

4. When one - fourth of the wave length of the incident sound approximated the length of the ear canal, resonance and antiresonances developed at the tympanic membrane. The problem could be remedied with the use of a probe microphone to measure the sound pressure level of the ear drum (Nevertheless, even probe microphones cannot overcome the problem of transverse waves above 15000Hz associated with a half wave resonance).

Tonndorf and Kurman (1984) overcame the calibration problem by using a special electric transduction mode in which 60Hz carrier frequency is moderated by the desired audio-frequency. The carrier frequency and the desired frequency were applied to the skin through the electrodes placed on both mastoids or on one mastoid and the arm.

According to Tonndorf (Personal communication, 1987) and Kurman (Personal communication, 1988) the procedure involving the special electric transduction mode has draw - backs when masking is introduced to the non-test ear; upon introduction of masking, measurement error occurs. Therefore, further research is needed on masking using the special electric transduction mode, before clinical feasibility of high-frequency air-conduction audiometry can be evaluated.

High-frequency bone conduction thresholds

High-frequency bone conduction thresholds have been obtained using mastoid placement of a specially constructed piezo electric bone-vibrator referenced in sound presure level (Corso,1964) and referenced in acceleration levels (Bednin and Sagalovich,1976) and using electrostimulation through an electrode type transducer (Tonndorf and Kurman,1984, Tonndorf,1985).

Richter and Frank, (1985) found stable mechanical impedance curves and force sensitivity curves for the B&K 4930 artificial mastoid upto 16000Hz. They also measured the frequency response curves between 8000 and 16000Hz for several electromagnetic type bone-vibrators calibrated with the B&K 4930 artificial mastoid. They found that all the bone vibrators, except the Atlask and Pracitronic KH-70 bone vibrators, had poor test-retest reliability. Since Pracitronic KH-70 had a higher output than the Atlask for the same input voltage, Richter and Frank (1985) recommended the use of the Pracitronic KH-70 for high-frequency bone-conduction audiometry.

Frank and Ragland,(1987) evaluated the test - retest reliability of high-frequency bone-conduction thresholds between 8000 and 16000Hz using the Pracitronic KH-70 bone-vibrator calibrated with a B&K 4930 artificial mastoid. The puretone stimuli were generated from an oscillator monitored by a frequency counter.

The results, obtained on a group of 30 subjects with normal hearing thresholds between 250 to 8000Hz, revealed that the initial bone - conduction thresholds were not significantly different from the retest bone - conduction thresholds, regardless of whether or not the bone vibrator was replaced at the repeat session.

Future research is needed to assess the relation between the high - frequency air-conduction and bone-conduction within a given subject, to determine whether masking for high-frequency bone-conduction is needed, and to develop a bone vibrator with a higher output level than the KH-70, particularly at 16000Hz (Frank and Ragland 1987).

High-frequency auditory brainstem evoked response audiometry

The auditory brain stem response technique has gained widespread acceptance as an objective diagnostic prodecure in the fields of audiology and neuro-otology for the evaluation of auditory function. ABR is useful for diagnosis of retrocochlear pathology, intra operative monitoring and in the estimation of hearing thresholds in neonatal or other difficult-to-test populations.

The most common stimulus for evoking the ABR is the electrical square wave, which generates an acoustical click stimulus. The spectral properties of a click, although broad-band, are shaped by the resonant properties of the earphone and its coupling to the ear, with typical concentration in the 2-to 4- kHz region (Mitchell et al (1989)

ABRs elicited from high frequency (8 kHz) tone bursts may also prove to be clinically useful. Loss of hearing sensitivity due to ototoxicity usually occurs initially in the highest frequencies tested, spreading eventually to lower frequencies (Fee 1980, Fausti et al 1984 a,b; Kopelman et al, 1988 ; Matz 1990)

Research utilizing high frequency (8kHz) tone brust stimuli to elicit ABRS is limited Fausti et al (1991a) and Gorga et al (1987) have demonstrated that high frequency specific tone bursts can be used to evoke measurable ABRs in normal hearing person. Intra -and intersession reliability of these responses has been demonstrated in a normal hearing population with a system designed for laboratory use (Fausti et al 1991) A portable high -frequency tone burst stimulus generator was designed and constructed to investigate high frequency ototoxic hearing loss in patients who cannot be brought to the laboratory for testing. This portable ABR unit has been shown to produce reliable ABRs in a normal hearing group of individuals (Fausti et al., in press)

Recent studies have demonstrated that, in normal hearing persons, reliable ABRs can be obtained with high frequency (> 8kHz) tonebursts (Fausti et al 1991 a, b ; 1992a, 1993b, Gorga et al,1987). Fausti et al (1992b) have used high frequency tone - burst - evoked ABR concurrently with behavioural audiometry (conventional-and high-frequency) during prospective monitoring of responsive patients receiving treatment with known ototoxic drugs. Results revealed that 90% of the ears demonstrating ototoxic hearing loss by behavioural audiometry also had a significant wave V latency shifts Criteria for identifying latency changes ($\geq$ 0.3 msec) or loss of a previously obtained respons were based upon high-frequency tone-burst ABR latency values obtained from normal - hearing individuals in test-retest reliability and latency-intensity function (LIF) studies (Fausti et al 1991 b, 1993 b).

An independent project by Radhika, in 1988 from the University of Mysore on High frequency audiometry - A review - gives us the detail about the studies on development, instrumentation and clinical implications of high frequency audiometry from its time of conception to the year 1988.

The following chapters will deal about the various aspects of high-frequency audiometry studies during the period from 1988 to 1998.

METHODOLOGY

The present study is a review about the studies done an high-frequency audiometry for the past ten years (i.e.) 1988 to 1998.

Aim of the Study:

The study aimed at bringing into light, about the development of high-frequency audiometry in the are of audiological testing as well as its methodological developments.

Based on the various studies done by various authors in the field of high-frequency audiometry the review topics are divided into:

- Methodological, Age and Sex differences
- Equipments and Accessories
- Masking
- Clinical implications
- High-frequency immitance audiometry
- High-frequency auditory brainstem evoked potentials.

To go about the review, various journals and books which were published during the years 1988 to 1998 were browsed through. The main source of information were journals and these journals were available at the library of All India Institute of Speech and Hearing, Mysore.

Information was also available from Scientific update and News Scan (SUNSCAN), Sun Pharmaceutical Industries Ltd., Gujurat, India.

The review is arranged in a chronological order under each sub-title.

HIGH FREQUENCY AIR CONDUCTION AND BONE CONDUCTION AUDIOMETRY METHODOLOGICAL AGE AND SEX DIFFERENCES

Since Rosen et al,(1964) published their study concerning high-frequency hearing and ageing, numerous studies using normative materials have been published on high-frequency air - conduction audiometry. In these studies several different techniques have been employed. In addition to the methodological differences, there are differences in population characteristics and selection criteria, calibration techniques testing methods and environment, stimulus presentation and patient response procedures, all of which make comparisons between these studies difficult. In the following discussion we shall see the studies done by various authors regarding these aspects from the year 1988 to 1998.

Filipo, .., Deseta, ., Bertoli, (1988) defined the ultra-audiometric threshold in a group of children, eight to ten years of age using a home-made audiometer which produces tones at 8,10,12.5,16 and 20 kHz through a circumaural head phone in which a loudspeaker (Motorola KSA50) was fitted. The test was carried out on two groups of subjects (1) 25 children (11 boys and 4 girls) ---> 7-10 years of age (2) 20 youths (10 males and 10 females) —> 17 to 20 years. The results showed that there was no statistically significant difference "found either between right and left ears, or between males and females in the two groups. There was a progressive threshold increase in the older subjects for 16kHz upwards which assumed statistical significance at 20kHz (Fig (1), Table (1) and Table (2)

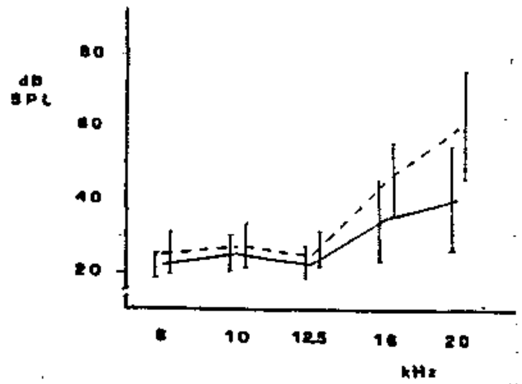
Table-(l) Mean threshold values (dB SPL) and standard deviations obtained from males and females in the children group; data rounded to nearest decibel.

	Frequency, kHz				
	g	10	12.5	16	20
Males					
Mean	23	25	23	35	40
SD	4	5	4	10	13
Females					
Mean	21	26	22	35	41
SD	4	5	3	11	14

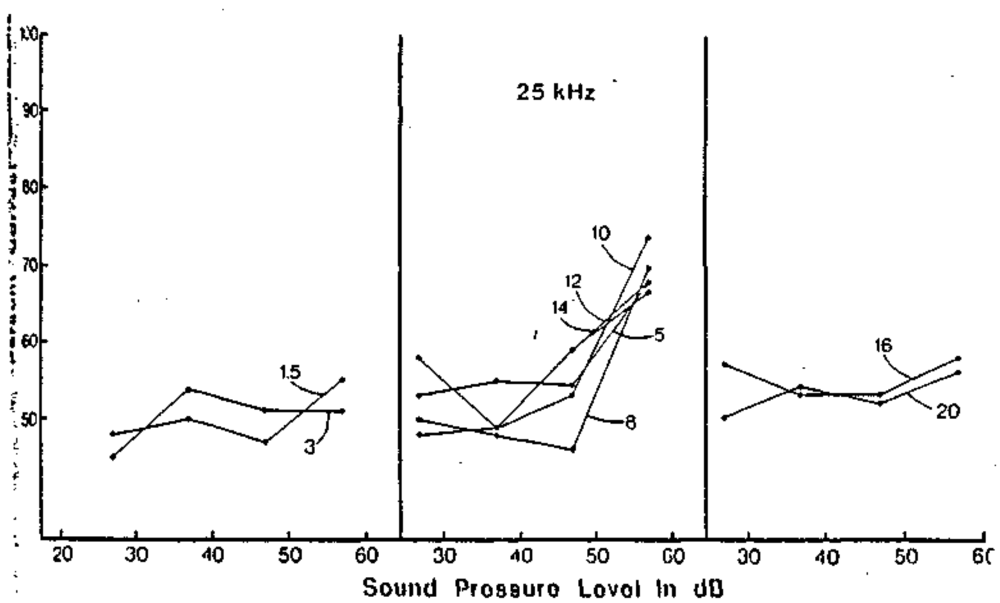
Table-(2) Mean threshold values (dB SPL) and standard deviations obtained from males and females of the group of youths; data rounded to nearest decibel.

	Frequency, kHz				
	8	10	12.5	16	20
Males					
Mean	24	27	25	46	61
SD	5	4	4	13	17
Females					
Mean	25	27	23	45	58
SD	4	4	4	14	18

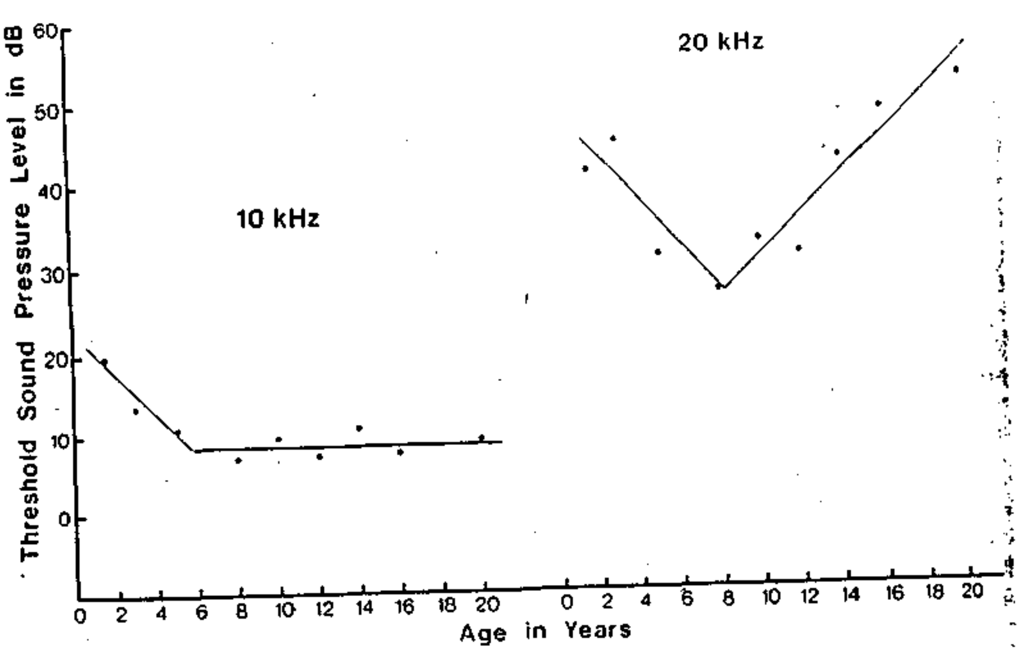
Trehub, , Schneider, ? ., Morrongiello, ., Thorpe, (1989) explored the development of high-frequency sensitivity during the first two decades of life. They attempted to specify the sensitivity of listeners between 1.5 and 20 years of age to 1/3 octave - band signals with center frequencies of 10, 20 and 25 kHz, the pattern of development of high



Fig(1): Mean threshold values and SD for the children examined, in comparison with the 17-20-year-old group (dotted).



Fig(2): Percentage of correct responses as a function of sound pressure level for ⅓-octave-band noise centred 25 kHz. Age of listeners is indicated in years.



Fig(3) :Absolute thresholds defined as 65% correct responding as a function of age for ⅓-octave-band noise centred at 10 and 20 kHz.

-frequency sensitivity, sensitivity of children to a higher frequency stimulus ie 25 kHz and also the age at which the decline in high-frequency sensitivity becomes apparent. The subjects taken were 20 adults between 17 to 25 years age and 200 children between 1.5 years and 16 years of age. (ie) 36 children each of 1.5 years and 3 years, 27 children of 5 years, 21 children of 8 years and 20 children at each of 10, 12, 14 and 16 years of age. The listeners of 1.5 and 3 years of age as well as those of 16 and 20 years of age were unable to detect the 25 kHz signal at its highest intensity (57dB). In contrast listeners, 5-14 years of age could detect the 25 kHz signal. Sensitivity to the 20 kHz signal improved until about eight years of age, deteriorating gradually thereafter. Sensitivity to the 10kHz signal improved rapidly reaching young adult levels by five years of age, and remaining stable until 20 years of age. (Fig (2) and Fig (3))

These findings were consistent with the onset of high-frequency hearing losses at around 10 years of age (ie) the histological findings of gradual hair cell loss with corresponding nerve degeneration ascending from the basal end of the cochlea over the first two decades of life (Bredberg 1967, Johnson and Hawkins 1972). Some of the age related changes in high-frequency sensitivity could be due to the developmental changes in the mechanical characteristics of the outer and middle ear ((i.e) the external auditory canal and pinna are smaller for young than for older children), which would increase the effective intensity of some high-frequency signals for younger children (Saunders et al 1983, Shaw 1974).

Stelmachowicz, Beauchaine, . Kalberer, Jesteadt, (1989) conducted a study to obtain normative threshold values as a function age and sex from listeners in the 10 to 59 year age range using the prototype high frequency audiometer described by Stevens et al (1987).

This audiometer consisted of an Apple II e microcomputer, an amplifier, acoustic transducer, and several peripheral devices. The high-frequency transducer was coupled to the ear brass earpiece encased in a rubber cuff. The ear- canal via a 60-cm plastic tube that terminated into a brass earpiece is held in place in the ear canal with a specially constructed headset. Near the end of the earpiece, a miniature microphone is suspended within the tube via thin wires. The microphone was used to measure the impulse response of the entire system for each subject. The Fourier transform (FT) of this response is computed, and an individual calibration function is generated from the location and band width of zeros. The calibration function was used to convert nominal attenuator values to dBSPL at the medial end of the ear canal. Levels expressed in dBSPL were 15 to 18dB greater, on average, than nominal attenuator values. In some instances, factors such as an inadequate placement of the earpiece or unusual ear canal geometry caused anomalies and/or irregularities in the fourier transform. This generally occurred in the higher frequencies. To estimate the sound pressure level (SPL) in these cases, the average correction values, computed for frequencies below the point where these anomalies accured, were used to correct the nominal attenuator settings to dBSPL. The remaining SPL estimates for these cases will be referred to as extrapolated values.

In the above study, 240 subjects ranged in age from 10-59 years, were evaluated. These subject were divided into 15 age categories with 16 subjects per age group. Groupings were in one year intervals from 10 to 19 years, in five year intervals through 30 years and in 10 year intervals through 59 years. There were equal numbers of males and females within each group.

The results of the study showed the following -

- The calibration values showed no significant effects of frequency, age or sex.
- Similar results were shown regardless of whether thresholds were expressed in nominal or SP1 terms.
- Thresholds increase monotonically as a function of frequency for all age groups and increased monotonically as a function of age at almost all frequencies (Fig(4) and (5)).
- Large changes in sensitivity were apparent between the 30- to 39-year old group and the two older age groups at all frequencies.
- Changes in sensitivity were apparent between the 30-to 39- year old group and the two younger age groups only at frequencies above 13kHz.
- Less of hearing sensitivity as a function of age is most rapid in the 15-to 18-kHz range.
- At lower frequencies, changes are minimal until approximately 40 to 49 years of age.
- At higher frequencies, changes begin at an earlier age, but do not progress as rapidly. (Between approximately 112 and 120dB many of the subjects of the study reported that the signals changed in quality, were atonal in nature, or that the percept was one of "pressure" in the ear canal rather than a true auditory sensation. These perceptual changes did not occur at the same level for all listeners. Stevens et al (1987) reported similar problems

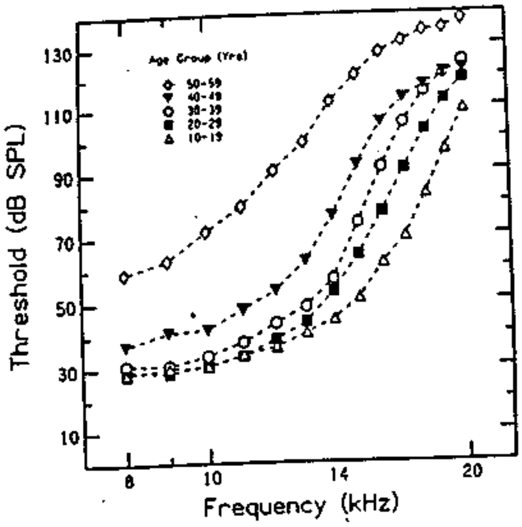


Fig (4) Mean threshold (dB SPL) as a function of frequency (kHz). The paramenter is age group.

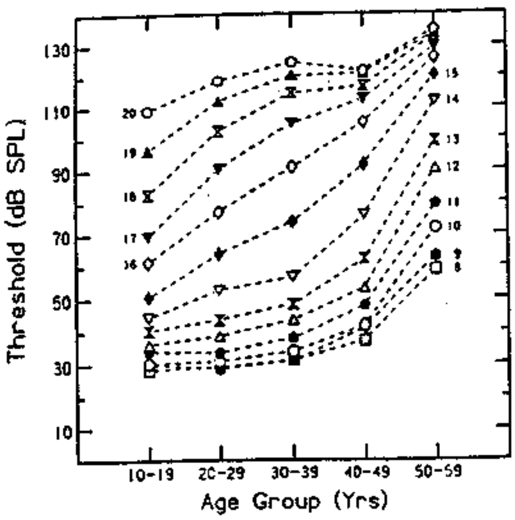


Fig (5) Mean threshold (dB SPL) as a function of age group in decade intervals. The parameter is signal frequency (kHz).

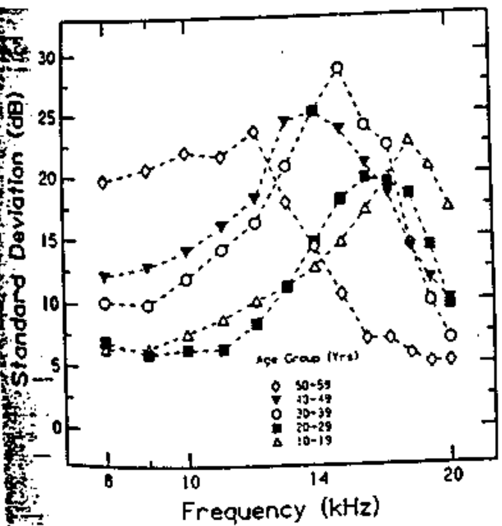


Fig (6) Intersubject standard deviation (dB) as a function of frequency (kHz) for the five age groups noted. Standard deviations were computed by dividing sums of squares by $N - 1$, rather than N, and thus provide estimates of variability in the population independent of sample size.

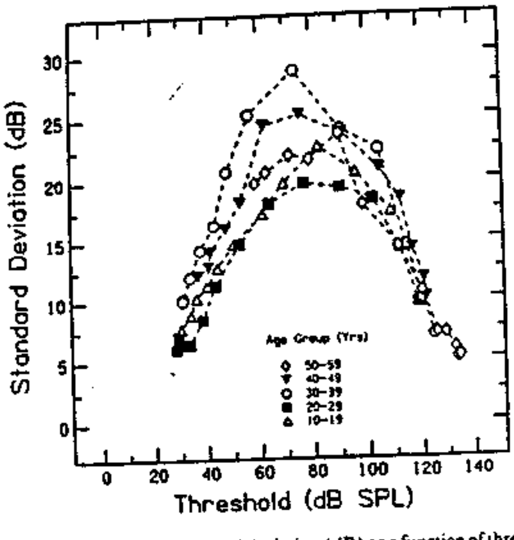


Fig (7) Intersubject standard deviation (dB) as a function of threshold (dB SPL) for the five age groups noted.

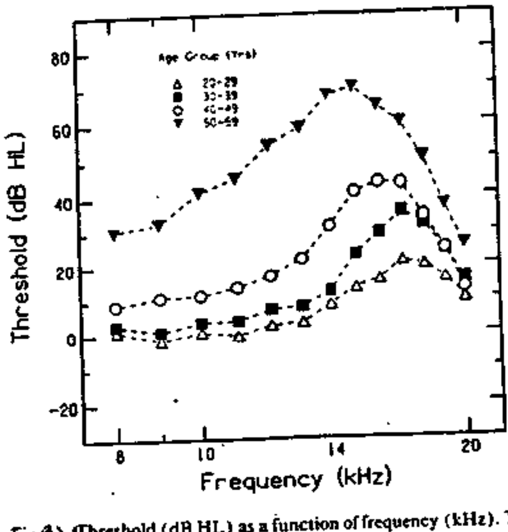


Fig (8) Threshold (dB HL) as a function of frequency (kHz). The parameter is age group. The reference threshold levels are based upon data from 160 subjects in the 10- to 19-year age range.

with this prototype audiometer. Their empirical measures suggested, that the maximum levels which can be presented in the 16 to 20 kHz without low frequency cues,are 110 to 120 dB.

- Inter-subject variability in the study is showing Fig.(6) for all the five age groups, the standard deviation increases as a function of frequency, reaches a maximum value between at 12 and 16 kHz, and then decreases markedly. The frequency, at which the maximum occurs systamatically, decreases as a function of age, and the maximum is considerably broader and less well defined in the older age groups. In the frequency region below the maximum, the standard deviation increases as a function of age. The changes in variability as a function of both frequency and age in the region below the maximum are to be expected and are consistent with earlier data. The decrease in variability at higher frequencies also was consistent with earlier reports. (Schechter, et al 1986: Dreschler and Vander Hulst, 1987: Green, et al 1987).
- The age related trends are related to the absolute thresholds rather than to age perse. The down-ward shift in the maxima as a function of age would support this hypothesis. It was apparent from Fig.(7) that, for all age groups, the maximum standard deviation occured in the 70 to 80 dB range. At both lower and higher thresholds levels, the inter subject variability was considerably lower.
- While thresholds (in dBSPL) increase monotonically as a function of frequency all age groups, those increases to do not necessarily represent hearing loss. To a large extent,differences in the thresholds of audibility as a function of frequency reflect the transfer function of the middle ear

(Moller,1972 and Kurman,1984: Okstad et al 1988). Because no change was observed is thresholds for the one year intervals from 10 to 19 years of age, it is reasonable to assume that hearing loss has not yet occured in the 8 to 20 kHz frequency region within that age range. The mean threshold for the 160 subjects in the 10 to 19 year age groups can be used, therefore as a normative reference that presumably reflect the transfer function of the middle ear in this frequency region. Means and standard deviations for this age group are shown in Table (3). Thresholds for the remaining four age groups can be expressed in terms of hearing level, or dBHL, by substracting the values in Table (3) from the thresholds in dBSPL. In Fig. (8), the pattern of hearing loss as a function of frequency and age is shown following this transformation. When data is converted to dBHL, the region of maximum hearing loss shifts to lower frequencies with increasing age, and thresholds shifts with age are greatest in 13 to 17 kHz range.

Table 3: Mean thresholds and intersubject standard deviations for subjects in the 10- to 19-years-old range (N = 160).

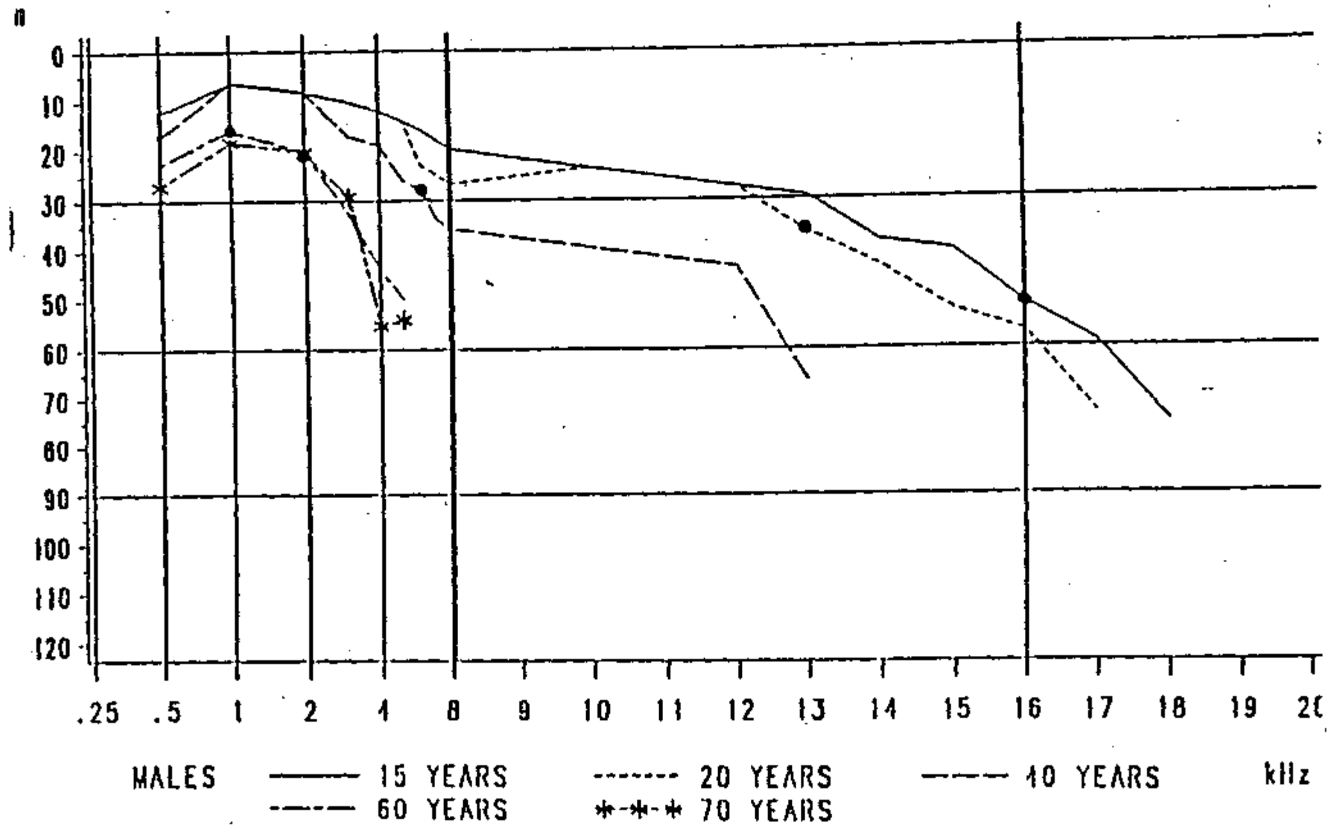
Frequency (kHz)	Mean	s.d.
g	28.29	6.40
9	30.12	6.50
10	30.38	7.64
11	34.06	8.76
12	36.26	10.18
13	40.36	11.18
14	44.30	12.68
15	50.60	14.65
16	61.42	17.17
17	69.43	19.67
18	82.64	22.57
19	96.25	20.51
20	108.96	17.27

Löppönen, Sorri, Bloigu, (1991) had conducted a study to obtain average threshold values for both sexes and different age groups, measured with an electric bone-conduction and high-frequency air-conduction audiometers. In the study 208 subjects (115 males and 93 females) divided in-to five different age groups (table 4) were taken and they had normal pneumatic otoscopic findings. They used Madsen OB 822 clinical audiometer to measure the conventional frequencies (125 to 8000 Hz) and AS 10 HF audiometer to measure the high-frequency air-conduction measurements. The electric bone-conduction thresholds were measured using Audimax 500 audiometer with mylar coated electrodes.

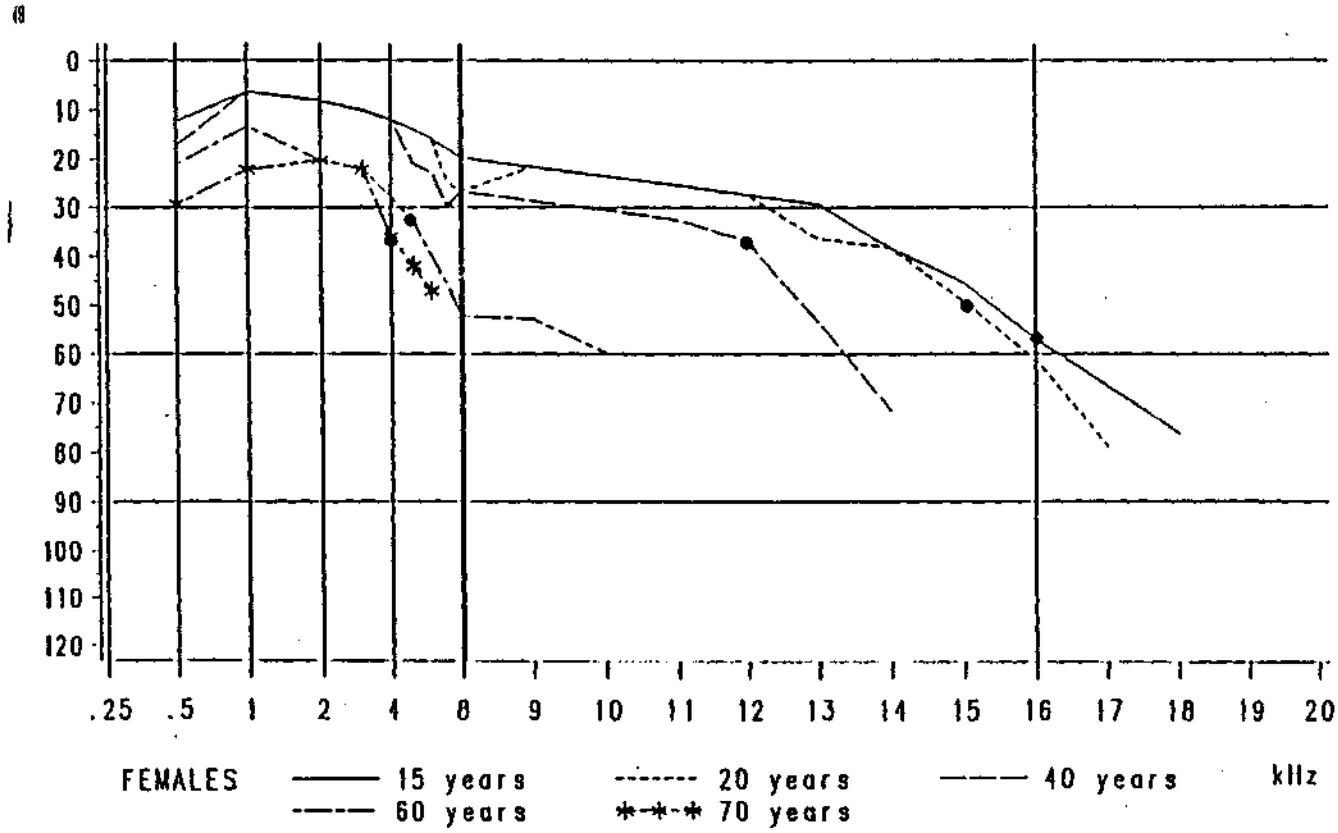
Table-4: Age and sex distribution of 208 subjects in the present study.

Age group	No. of subjects	Median age (range)
15-male	15	14(10-17)
15-female	14	13(9-17)
20-male	28	20(19-26)
20-female	27	23(18-27)
40-male	21	41(40-41)
40-female	22	40(37-43)
60-male	20	60(60-61)
60-female	19	61(60-61)
70-male	11	71(71-72)
70-female	11	71(71-72)

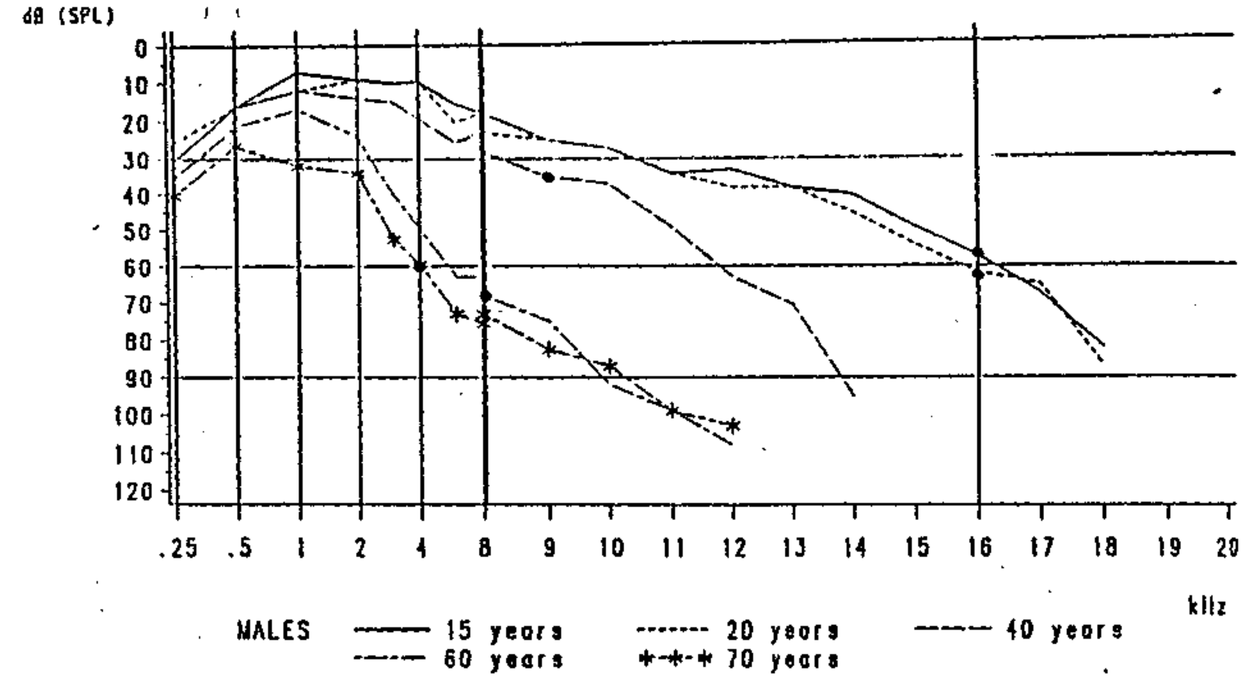
Fig. 9-12 shows the median threshold of all age groups. Table 5-6 shows the median, 10th and 90th percentile and means for males and females of different age groups measured with electric bone-conduction and air-conduction audiometers.



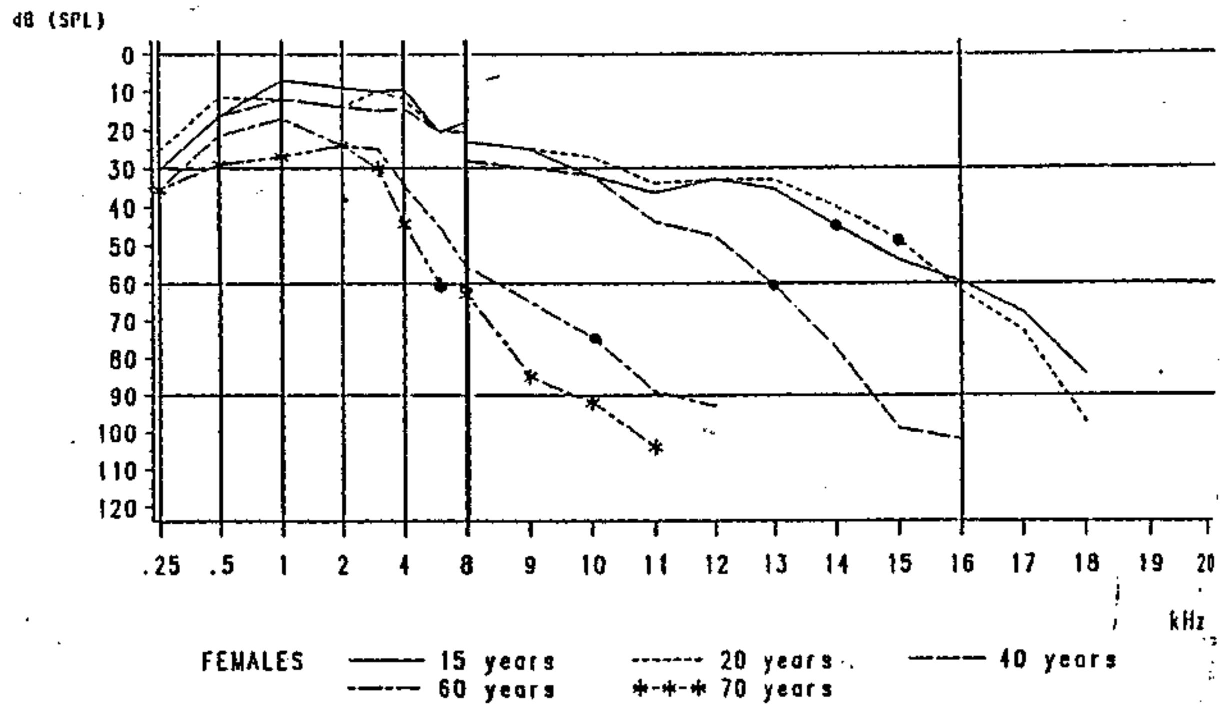
Fig(9):Median binaural electric bone-conduction thresholds (equivalent to dB SPL according to 40 log (i) re 1 mA and frequency-dependent correction) for males in different age groups. On each curve the black dot denotes the highest frequency where all the subjects of the group respon test signal. The abscissa is logarithmic in the con frequency range and linear from 8 to 20 kHz.



Fig(10):Median binaural electric bone-conduction thresholds (eqnivalent to dB SPL according to 40 log (i) re 1 mA and frequency-dependent correction) for females in different age groups. On each curve the black dot denotes the highest frequency where all the subjects of the group responded ' test signal. The abscissa is logarithmic in the convenl frequency range and linear from 8 to 20 kHz.



Fig(11)- Median air-conduction thresholds (dB SPL re 20 uPa) for males in different age groups, thresholds of both ears being included in the calculations. Frequencies 0.5-8 kHz measured with Madsen OB 822 audiometer and 8-18 kHz measured with Interacoustics AS 10 HF audiometer. On each curve the black dot denotes the highest frequency where ll the subjects of the group responded to the test signal. Tb abscissa is logarithmic in the conventional frequency ran? and linear from 8 to 20 kHz.



Ftg(12) Median air-conduction thresholds (dB SPL re 20 uPa) for females in different age groups, thresholds of both cars being included in the calculations. Frequencies 0.5-8 kHz measured with Madsen OB 822 audiometer and 8-18 kHz measured with lntcracoustics AS 10 HF audiometer. On each curve the black dot denotes the highest frequency where the subjects of the group responded to the test signal.! abscissa is logarithmic in the conventional frequency re and linear from 8 to 20 kHz.

Table 5: Electic bone-conduction thresholds (equvalent to dB SPL according to 40 log (i) re 1 mA and additive frequency-dependent correction) and air-conduction thresholds (dB SPL re 20 uPa) for males including median 10th and 90th percentiles, and means (nm = not measurable).

EBC = electric bone-conduction thresholds, 0.5 -18 kHz (Audimax 500)
AC = conventional air-conduction thresholds, 0.5-8 kHz (Madsen OB 822)
HF AC = high-frequency air-conduction thresholds, 8-18 kHz (Interacoustics AS 10 HF)

		EBC/AC						EBC/HF AC					
Age group		0.5 kHz	1 kHz	2 kHz	4 kHz	6 kHz	8 kHz	8 kHz	10 kHz	12 kHz	14 kHz	16 kHz	18 kHz
15-	Median	12/17	6/7	8/9	12/10	16/16	20/18	20/18	24/27	27/33	38/40	51/57	75/82
	10th	5/12	-5/7	-4/9	0/10	4/16	15/13	15/13	12/17	23/28	31/35	35/42	43/57
male	90th	24/22	15/17	13/24	15/15	25/25	27/28	27/33	31/37	35/49	50/61	69/82	nm/98
	Mean	12/16	5/11	5/13	7/12	16/18	21/18	21/21	23/28	29/35	38/44	52/59	nm/nm
20-	Median	12/17	6/12	8'9	12/10	23/21	27/18	27/23	24/27	27/38	43/45	57/62	nm/87
	10th	5/12	6/7	7/9	12/5	16/16	20/13	20/13	36/42	27/23	31/35	42/42	nm/57
male	90th	18/22	13/17	15/19	19/20	28/31	27/28	27/34	28/28	39/54	55/75	nm/92	nm/107
	Mean	12/15	8/11	9/12	14/12	21/23	24/21	24/25	40/37	32/38	nm/49	nm/63	nm/nm
40-	Median	17/17	6/12	8/14	19/20	28/26	37/23	37/28	24/24	43/63	nm/95	nm/nm	nm/nm
male	10th	12/12	6/7	8/9	12/11	17/16	20/30	20/80	nm/81	27/33	nm/57	nm/nm	nni/nm
	90th	31/22	22/17	24/19	37/43	45/54	nm/57	nm/62	nm/nm	nm/102	nm/nm	nm/nm	nm/nm
	Mean	19/17	10/13	13/15	21/24	29/30	nm'29	nm/34	nm/92	nmmm	nm/nm	nm/nm	nnvnm
60-	Median	23/22	16/17	20/24	44/50	nm/63	nm'63	nm/68	nm/58	nm/108	nm/nm	nm/nm	nm/nm
	10th	13/17	7/12	8/9	19/20	run/26	run/29	nm/34	nm/nm	nm/98	nm/nm	nm/nm	nm/nm
male	90th	45/42	39/37	nm/58	nm/85	nm/96	nm/103	nm/103	nm/nm	nm/nm	nm/nm	nm/nm	nm/nm
	Mean	24/26	17/24	nm/30	nm/51	nm'63	nm/63	ran/67	nnv'87	nm/nm	nm/nm	nm/nm	nm/nm
70-	Median	27/27	18/32	20/34	55/60	nm/73	nm/76	nm/73	nm/54	nm/103	nm/nm	nm/nm	nm/nm
	10th	14/12	6/12	8/14	14/23	nm/46	nm/31	nm/30	nm/nm	nm/78	nm/nm	nm/nm	nm/nm
male	90th	36/62	34/57	41/71	nin/95	nm/nm	nm/nm	nm/107	nm/nm	nm/nm	nm/nm	nm/nm	nm/nm
	Mean	27/30	20/30	22/38	nin/61	nm/nm	nm/nm	nm/72	nm/nm	nm/nm	nm/nm	nm/nm	nm/nm

Table 6 : Electric bone-conduction thresholds (equivalent to dB SPL according to 40 log (I) re 1 mA and an additive frequency-dependent correction) and air-conduction thresholds (dB SPL re 20 uPa) for females including median 10th and 90th percedntiles, and means (nm=not measurable)

EBC = electric bone-conduction thresholds, 0.5-18 kHz (Audimax 500)
AC = Covenlional air-conduction thresholds, 0.5-8 kHz (Madsen OB 822)
HF AC = high-frequency air-conduction thresholds, 8-18 kHz (Interacoustics AS 10 HF)

		EBC/AC						EBC/HF AC					
Age group		0.5 kHz	1kHz	2kHz	4 kHz	6 kHz	8 kHz	8 kHz	10 kHz	12 kHz	14 kHz	16 kHz	18 kHz
15- female	Median	12/17	6/7	8/9	12/10	16/21	20/18	20/23	24/32	27/33	38/45	57/60	76/85
	10th	12/12	-1/7	-4/9	0/10	4/15	8/13	8/15	12/14	15/18	24/30	38/47	49/67
	90th	17/22	13/7	8/14	12/20	23/31	30/33	30/33	36/37	37/48	47/70	77/102	nm/nm
	Mean	13/15	7/10	6/11	7/12	11/21	19/20	19/24	24/29	28/33	36/56	57/nm	nm/nm
20- female	Median	12/12	6/12	8/14-	12/12	16/21	27/18	27/23	24/27	27/33	38/40	61/62	nm/97
	10th	5/12	-6/7	4/9	0/5	4/16	8/13	8/13	12/17	27/18	31/25	41/37	nm/62
	90th	23/19	14/17	15/17	19/20	28/31	33/33	33/33	31/42	36/43	58/63	nm/97	nm/nm
	Mean	13/14	6/11	7/12	10/12	17/21	23/20	23/23	26/29	31/33	42/43	nm/nm	nm/nm
40- female	Median	17/17	6/12	8/14	12/15	23/21	27/21	27/28	31/32	33/48	72/78	nm/102	nm/nm
	10th	7/12	*-111*	-4/9	12/10	16/16	20/13	20/16	24/27	35/33	49/50	nm/90	nm/nm
	90th	26/17	18/17	19/19	19/22	31/36	32/28	32/36	38/42	55/63	nm/105	nm/nm	nm/nm
	Mean	17/14	9/11	9/15	14/16	24/23	27/21	27/26	31/34	41/47	nm/nm	nm/nm	nm/nm
60- female	Median	21/22	13/17	20/24	28/35	40/46	52/56	52/56	60/75	41/47	nm/nm	nm/nm	nm/nm
	10th	12/12	6/12	8/9	19/20	23/26	27/28	27/33	43/42	nm/93	nm/nm	nm/nm	nm/nm
	90th	38/42	37/37	39/44	43/60	nm/71	nm/73	nm/83	nm/98	nm/78	nm/nm	nm/nm	nm/nm
	Mean	22/23	16/21	20/26	29/37	nm/50	nm/52	nm/57	nm/73	nm/nm	nm/nm	nm/nm	nm/nm
70- female	Median	29/29	22/27	20/24	36/45	47/61	nm/61	nm/63	nm/92	nm/nm	nm/nm	nm/nm	nm/nm
	10th	8/12	8/14	8/19	13/21	24/32	nm/38	nm/43	nm/57n	nm/nm	nm/nm	nm/nm	nm/nm
	90th	nm/67	44/65	45/70	49/70	nm/89	nm/nm	nm/109	nm/116	nm/nm	nm/nm	nm/nm	nm/nm
	Mean	nm/32	22/31	21/33	34/43	nm/61	nm/nm	nm/70	nm/nm	nm/nm	nm/nm	nm/nm	nm/nm

The electric bone-conduction threshold curves illustrate the decrease in sensitivity at the higher frequencies with the advancing age, as also found with air-conduction measurements. Thresholds deteriorated as a function of age, particularly at the high-frequency range. The males had poorer thresholds than the females, especially in the age groups of 40 and 60 years. This could be attributed mainly to their greater noise exposure. A side (left and right) difference between the ears were found in the 40 year old males and 70 year old females, the left ear thresholds being higher. The reason for this side difference remains unknown.

Franke, & Dreisbach, (1991) studied about the repeatability of high-frequency thresholds. They studied 50 subjects (25 males and 25 females) of mean age 22.6 years. The puretones 10, 12, 14, 16 and 18 kHz were generated from a Beltone 2000 audiometer and directed to Senheiser HD 250 circumaural earphones. Intra-subject high - frequency thresholds were found to be repeatable for the 100 ears which were tested across four test sessions separated by one, but no more than two weeks. The threshold differences between each possible test session comparison were not significantly ($P>0.05$) different for ear, test session comparison, or frequency. Overall intra-subject high-frequency thresholds were found to be repeatable and within a clinically acceptable range of ± 10 dB for atleast 94% of the ears, regardless of test session comparison and frequency (Table 7).

Table 7 : Percentage ears (n=100) having threshold differences of +5. ±10, and >± 10 dB for each test session comparison and frequency

		Frequency (kHz				
Test Sesion Comparisons	Threshold Difference	10.0	12.0	14.0	16.0	18.0
Session 2 minus session 1	±5 ±10 >+10	85 96 4	85 96 4	82 96 4	80 95 5	80 95 5
Session 3 minus session 1	±5 ±10 >±10	84 97 3	86 98 2	85 95 5	81 96 4	77 85 5
Session 4 minus session 1	±5 ±10 >±10	82 97 3	84 96 4	82 96 4	84 96 4	80 94 6
Session 3 minus session 2	±5 ±10 >±10	84 97 3	85 96 4	83 97 3	80 95 5	83 94 6
Session 4 minus session 2	±5 ±10 >±10	86 96 4	88 96 4	85 97 3	79 96 4	78 95 5
Session 4 minus session 3	±5 ±10 >±10	86 96 4	86 97 3	85 97 3	80 96 4	82 95 5

Löppönen, H. and Sorri, M. (1991) tried to obtain correction factors for the electric bone-conduction measurements by comparing electric bone-conduction audiometer (Audimax 500 with mylar coated electrodes placed on each mastoid) and air - conduction high - frequency audiometer (Interacoustics AS 10 HF audiometer with Koss HV/IA). 147 subjects (84 males, 63 females) with normal hearing were taken for the normative material study. They were divided into three age groups. (Table 8).

Table-8: Age and sex distributions of 147 subjecs included in the study.

Age group	No. of subjects	Median age (range)
15-male	15	14(10-17)
15-female	14	13(9-17)
20-male	48	20(19-26)
20-featnale	27	23(18-27)
40t-male	21	41(40-41)
40-female	22	40(37-43)

The results showed that the electric current (i) used as a stimulus in the Audimax 500 audiometer can be converted in to decibels with a correction factor of 401og(i)rel mA. However a frequency dependent additive correction is needed. (Table 9).

These authors also studied another group of 24 subjects about the reproducibility of these methods. Reproducibility with the electric bone conduction audiometer was better than with the air conduction audiometer, in the high frequency range (Fig 13,14,15,16).

Benefits of high-frequency audiometry in monitoring hearing sensitivity of patients administered with ototoxic medications are well established. Thresholds, obtained within a sound suit have been proven reliable. It may however often be necessary for the audiologist to evaluate the patient at bedside. Valente, Potts , Valente , French St-George, Goebel (1992) determined whether there are significant differences present between high-frequency thresholds measured in a sound suite versus thresholds measured in a hospital room. In addition, the test-retest reliability of high frequency thresholds was determined, when measured in a hospital room. For 25 normal hearing subjects, results revealed that significant differences when measured in a hospital room and significant differences were not observed between thresholds measured in a sound suite versus those measured in a typical hospital room. In addition, differences between the initial and repeated thresholds obtained in the hospital room were not significant, and the differences were, for the most part, within + l0dB at all test frequencies.

Table-9: Frequency-dependent correction factors for the Audimax 500 audiometer necessary following to dB SPL.

Frequency	Correction factor (dB)
0.5	-11
1	-10
2	-8
3	-6
4	-4
6	0
8	4
9	6
10	8
11	10
12	12
13	13
14	15
15	17
16	19
17	21
18	23

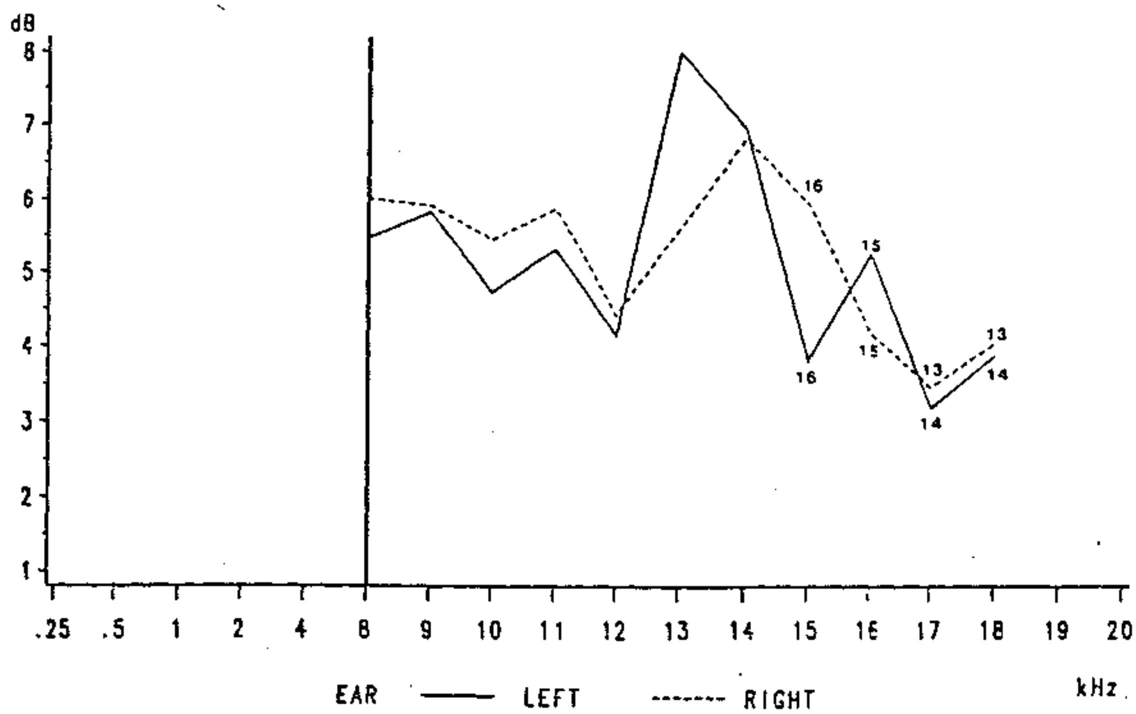
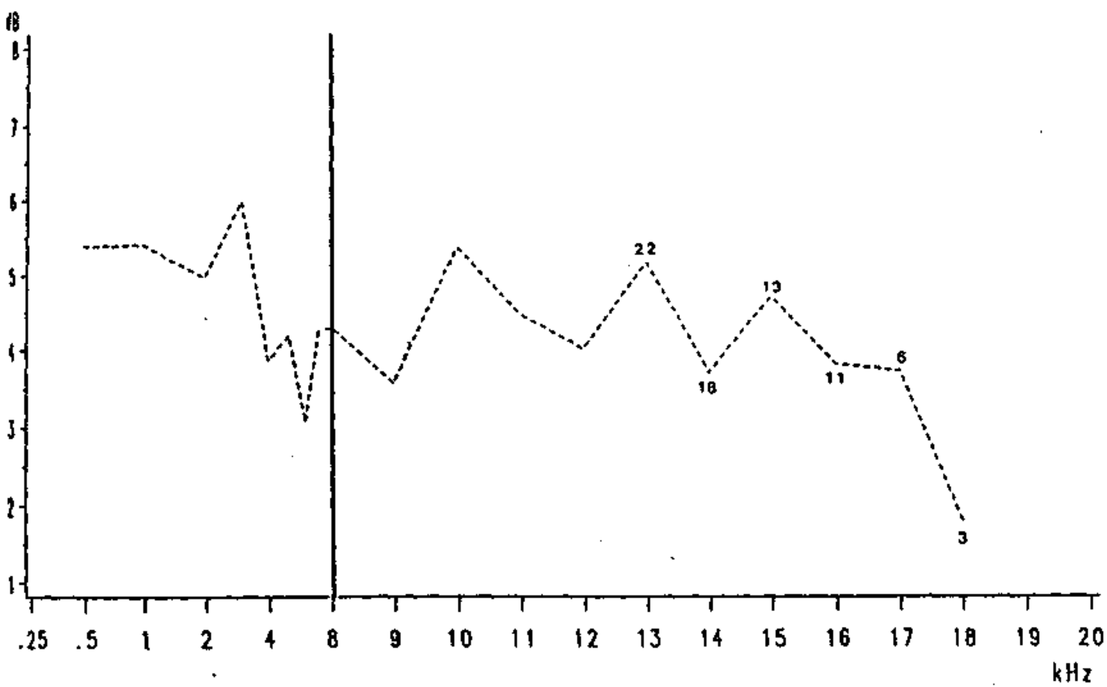
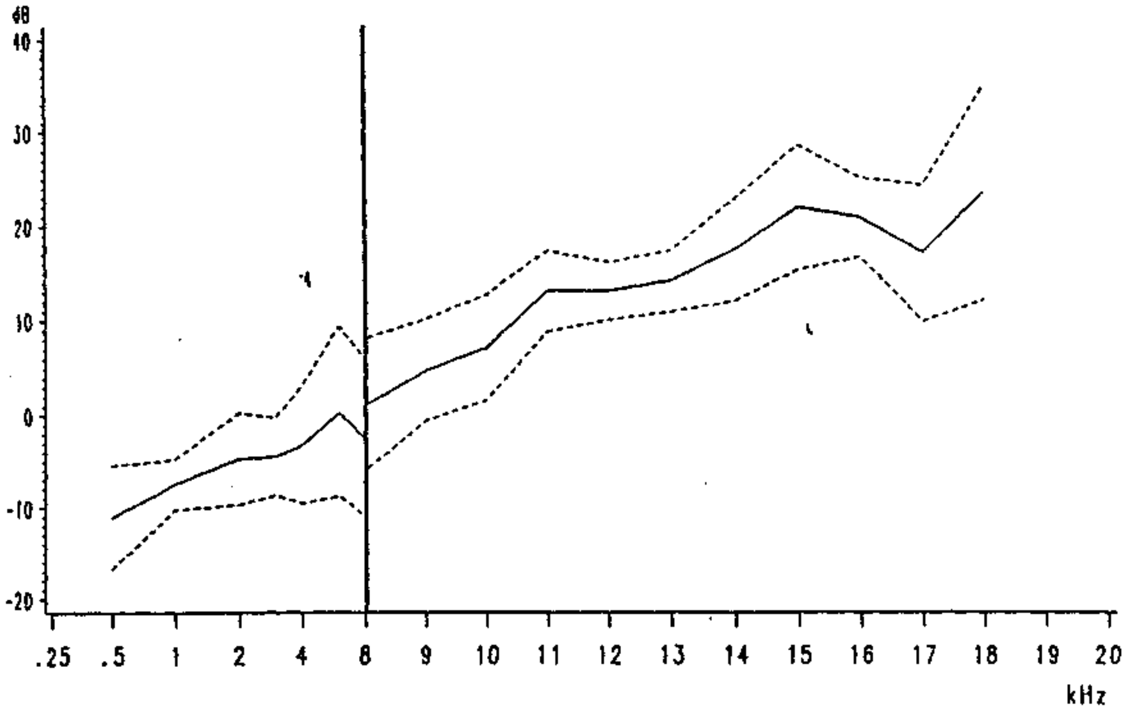


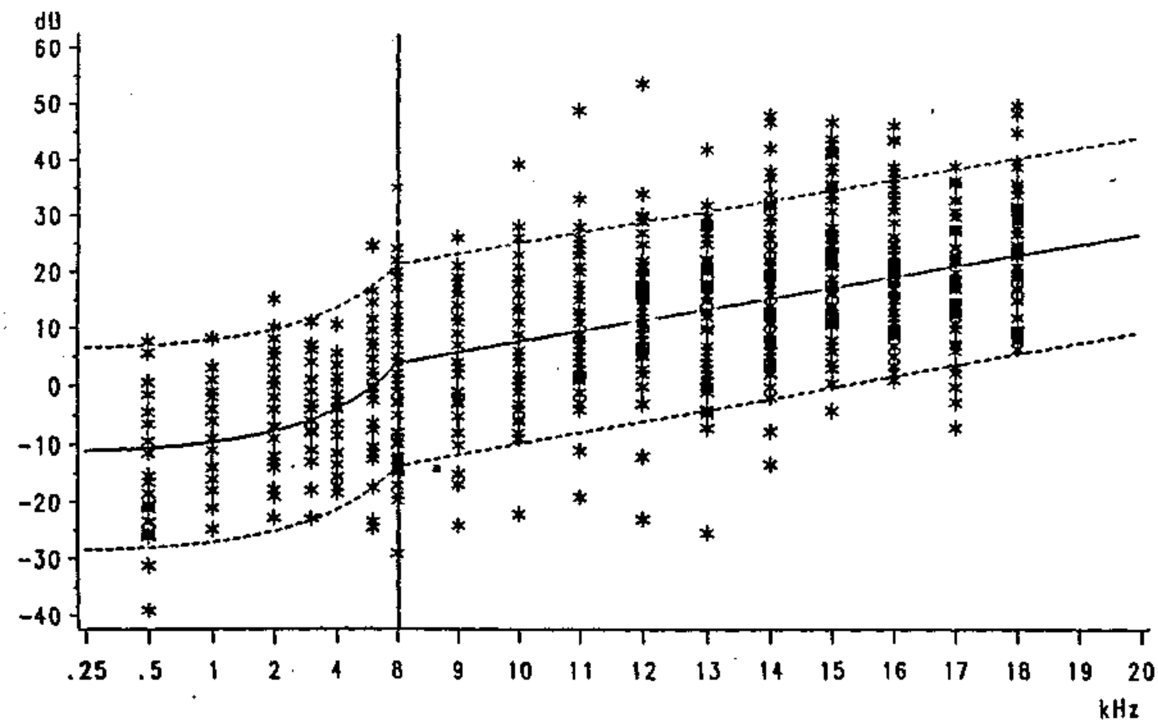
Fig.13: SDs of the differences from test-retest on 24 subjects measured with the Interacoustics AS10HF audiometer. Each subject was tested twiced during the same day, right and left ear separately. Numbers of subjects responding are included at 15-18kHz. Abscissa is logarithmic in the conventional frequency range and linear from 8 to 20kHz.



Fig(14)SDs of the differences from tcst-rctcst on 24 subjects measured with the Audimax 500 audiometer. Each subject vas tested twice during the same day. Numbers of subjects responding are included at 13-18 kHz. Abscissa is logarit mic in the conventional frequency range and linear from 8 20 kHz.



fig(15): Means and 2 SDs of AC/HHC difference for 147 subjects. AC thresholds are in dB SPL re 20 µPa, and the value for the ear with better threshold at each freqency has xen used. EBC thresholds have been converted to decibel notation according to the formula 40 tog (i) re 1 mA. Absci is logarithmic in the conventional frequency range and line from 8 to 20 kHz.



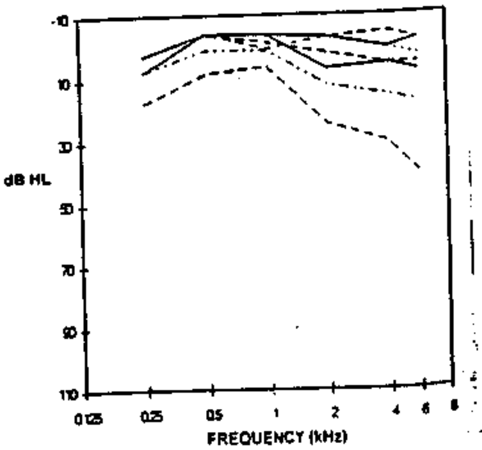
Fig(16): Scattogram of AC/EBC difference Tor 147 subjects. Linear regression analysis was performed lo calculate the regression line and 95% confidence intervals seen in the picture. Abscissa is logarithmic in (he conventional free range and linear from K to 20 kHz.

Hallmo, Sundby, Mair, . (1994), established normative values for the Pracitronic KH70 vibrator in extended high-frequency range of 8 through 16kHz in different age groups and in both sexes. 237 subjects were taken. The age and gender distributions of the subjects are shown in Table-10.

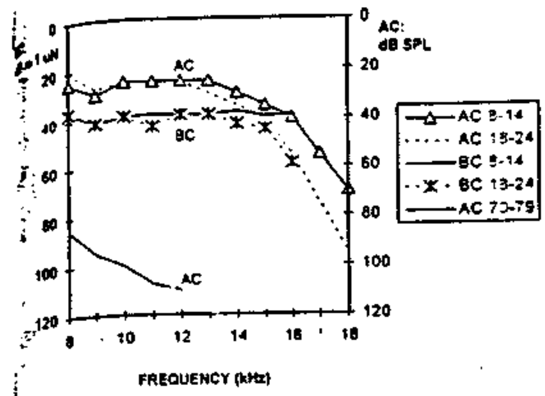
Table-10: Median and range of age in years, number and gender distribution of subjects, together with number of ears in each age group. F=femaies; M=males

Age in Years		Number of Subjects		
Range	Median (M F)	Male	Female	Ears
8-14	(12/9)	13	8	42
18-24	(21/22)	27	28	110
30-39	(35/34)	21	21	84
40-49	(45/45)	21	22	86
50-59	(56/53)	20	23	86
60-69	(66/65)	11	11	44
70-79	(73/76)	2	9	22
		115	122	474

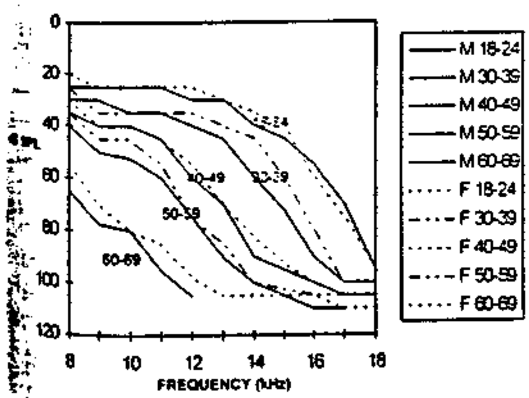
The instruments used in this study are Madsen OB70 audiometer in the conventional frequencies, Interacoustics AS 10HF in the extended high-frequency range through MX41/ARcushions and Koss HV/IA earphones respectively. BC puretones, generated through the same instruments in the conventional frequency and extended high-frequency ranges activated the Pracitronic KH70 bone vibrator. The median conventional bone-conduction thresholds for the different age groups reveal deteriorating thresholds with increasing age and for frequencies above 1kHz. The gender specific extended high-frequency air-conduction and bone-conduction thresholds for age groups and sex group have been shown in Fig. 17,18,19,20 and Table-11.



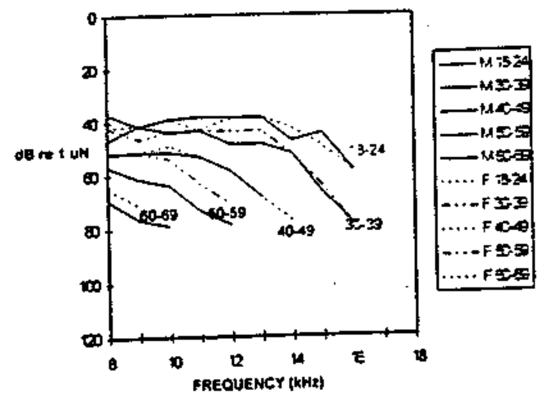
Fig(17): Median CF BC thresholds in the seven age groups. In this and the next figure both sexes have been included in the calculation of median values.



Fig(18): Median AC and BC EHF thresholds for the 8-14 and 18-24 years age groups and AC for the oldest, 70-79 years of age. In the latter group only 45% had BC responses at 8 kHz and even fewer at higher frequencies.



Fig(19): Median AC EHF thresholds for the five intermediate age groups for both females (F) and males (M). The former show a statistically non-significant tendency to lower thresholds above 30 years of age.



Fig(20): Median BC EHF thresholds for the five intermediate age groups for both females (F) and males (M). The maximum responding frequency is lower than for AC after 40 years of age. There is again a tendency for lower thresholds in females, but this is statistically significant only at 9 kHz in the 50-59 years age group.

Table 11 : Median and range of BC EHF thresholds (in dB re 1 uN) for each frequency and age group form males females in 11 A and 11 B respectively. No value is given when the number of reponders in a group was 50% or less (nm=not measurable)

	Frequency (kHz)								
Age	8	9	10	11	12	13	14	15	16
A 8-14 Median Range	37 32-52	37 27-57	39 24.49	38 28-53	39 2+49	34 24-54	35 23-53	37 20-50	39 19-54
18-24 Median Range	37 32-57	42 27. J7	39 24-59	38 23-63	39 24-64	39 19-64	48 23-73	45 25-80	59 29-nm
30-39 Median Range	47 32-67	42 32-72	44 34-79	43 28-78	49 29-79	49 29-nm	53 33-nm	67 30-nm	79 54-nm
40-49 Median Range	52 37-67	52 37-77	52 39-79	53 38-nm	59 34-nm	69 29-nm	38-nm	50-nm	59-nm
50-59 Median Range	57 37-82	62 37-77	64 34-nm	73 43-nm	79 49-nm	59-nm	78-nm	nm-nm	nnvnin
60-69 Median	69 52-nm	77 47-nm	79 42-nm	53-nm	69-nm	79-nm	nm-nm	nm-nm	nm-nm
70-79 Median Ran^e	67 nm	72-nm	nm-nm	nm-nm	nm-nm	nm-nm	nm-nm	nm-nm	nm-nm
B 8-14 Median Range	42 32-52	42 32-52	44 34-54	43 28-58	39 29-69	39 29-59	43 28-63	45 35-65	49 94-74
18-24 Median Range	42 27-52	42 27-62	39 29-59	43 28-58	39 24-54	39 24-59	43 233-68	50 25-80	59 34-nm
30-39 Median Range	42 32-57	47 27-57	44 34-64	43 33-68	44 34-74	44 29-79	53 33-nm	65 30-nm	74 49-nm
40-49 Median Range	52 37-72	52 32-72	49 34-74	53 33-nm	59 34-nm	69 39-nm	78 38-nm	50-nm	74-nm
50-59 Median Range	52 37-77	52 37-nm	54 39-nm	63 43-nm	71 44-nm	44-nm	48-nm	70-nm	nm-nm
60-69 Median Range	64 47-nm	72 47-nm	44-nm	53-nm	64-nm	74-nm	nm-nm	nm-nm	nm-nm
70-79 Median Range	57-nm	62-nm	74-nm	nm-nm	nm-nm	nm-nm	nm-nm	nm-nm	nm-nm

There was a tendency for age and frequency deterioration to be more pronounced in males, but it was statistically significant only for BC at 9kHz in the 50 through 59 years of age. Thresholds were higher for the 18-24 years group compared with 8-14 years from 13 and 14kHz for air-conduction and bone-conduction respectively. The clinical value of extended high-frequency audiometry in subjects above 50 years of age is restricted on account of the number of non- responders in older age groups.

Matthews, Lee, Mills, Dubno, (1997) measured thresholds at frequencies above 8kHz in older listeners (60- 79 years), who as a group, have elevated thresholds at lower frequencies. They also assessed, the test-retest reliability, age and gender effects and the influence of threshold below 8kHz. Their study included 162 older listeners (60-79 years) (Table 12).

Table-12: Number of participants and mean ages in two age groups categorized by gender.

	Age groups			
	60-69	70-79	Total	M
Male	51	44	95	70.0
Female	26	41	67	71.5
Total	77	85	162	70.6
M	66.9	74.0	70.6	

They used a Madsen OB 822 clinical audiometer with TDH- 39 head phones at the conventional frequencies and at the extended high-frequencies (8-18kHz) Demlar 20P high-frequency audiometer with Koss HV/1A head phones. Thresholds were measured once at the beginning of a one to two hour test session and then remeasured at the end of the test session. Extended high-frequency thresholds of older listeners with normal hearing at conventional audiometric frequencies were substantially higher than the thresholds reported for young listeners with normal hearing by Dreschler and vander Hulst (1987). Extended high-frequency thresholds of older listeners with hearing loss at conventional audiometeric frequencies were further elevated as compared to older listeners with normal hearing. Differences in extended high-frequency thresholds between males and females were either not present or were reduced when gender differences in conventional audiometric thresholds were taken in to account. (Fig 21 and Fig 26)

No significant differences were seen in thresholds at 8kHz and higher between 60 to 69 and 70 to 79 year old age groups. The results also indicated that thresholds above 8kHz can be measured in older listeners within a clinically acceptable ±10dB test-retest range. (Fig 22,23,24,25 and Table 13, 14,).

Table-13: Test-retest reliability (correlation) for EHF thresholds for frequencies from 8 through 12 kHz.

Frequency (kHz)	Right ear	Left ear
8	99	99
9	98	98
10	97	98
11	95	96
12	93	92

Fig (2.1): The upper panel plots the percentage of listeners with measurable thresholds at frequencies ranging from 8 through 18 kHz in each PTA group (i.e., normal [PTA ≤ 25 dB HL], mild-moderate [25 dB HL < PTA ≤ 50 dB HL], and severe [PTA > 50 dB HL]). Single asterisks indicate statistically significant differences ($p < .05$) between the normal and severe PTA groups. Double asterisks indicate significant differences between the normal PTA group and both the mild-moderate and severe PTA groups. The lower panel plots the percentage of male and female listeners with measurable thresholds at frequencies ranging from 8 through 18 kHz. Asterisks indicate statistically significant differences ($p < .05$).

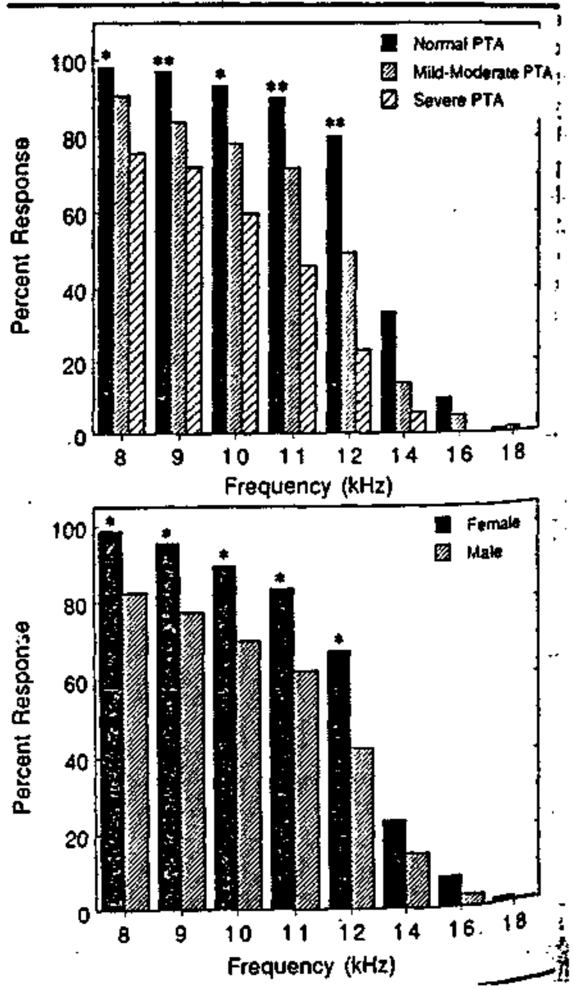


Fig (2.2): Mean conventional and EHF thresholds (dB SPL) for the normal PTA group of the current study and for a group of normal hearing 21- to 30-year-olds and 61- to 70-year-olds as estimated from Figure 1 of Dreschler and van der Hulst (1987).

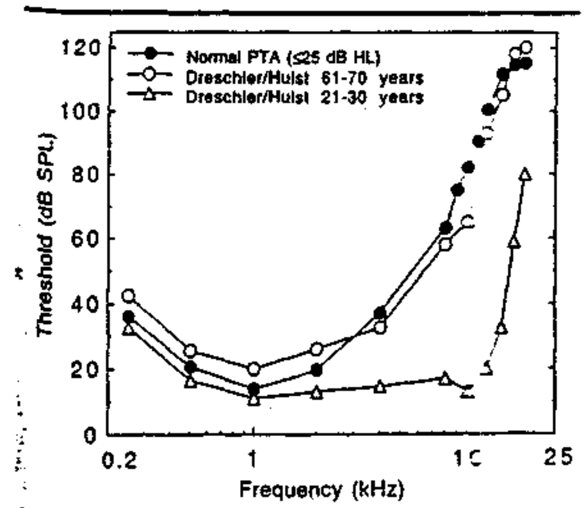


Fig (2.3): Mean conventional and EHF thresholds (dB SPL) for the normal (PTA ≤ 25 dB HL), mild-moderate (25 dB HL < PTA ≤ 50 dB HL), and severe (PTA > 50 dB HL) PTA groups.

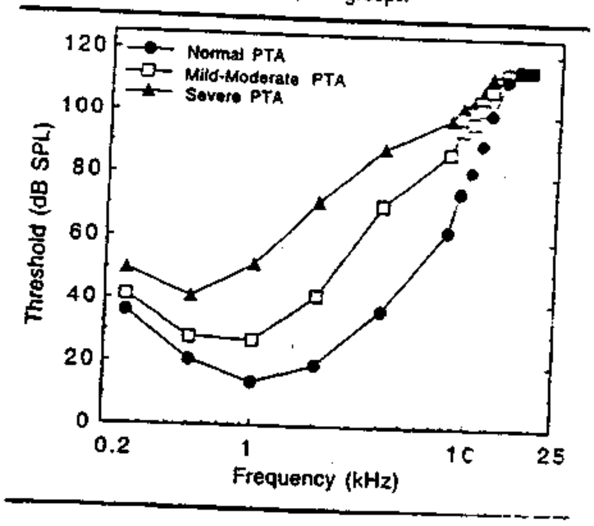


Fig (24): Mean EHF thresholds (dB SPL) for the normal (PTA ≤ 25 dB HL), mild-moderate (25 dB HL < PTA ≤ 50 dB HL), and severe (PTA > 50 dB HL) groups. Single asterisks indicate statistically significant differences ($p < .05$) between the mild-moderate and the severe PTA groups. Double asterisks indicate significant differences between the normal PTA group and both the mild-moderate and severe PTA groups.

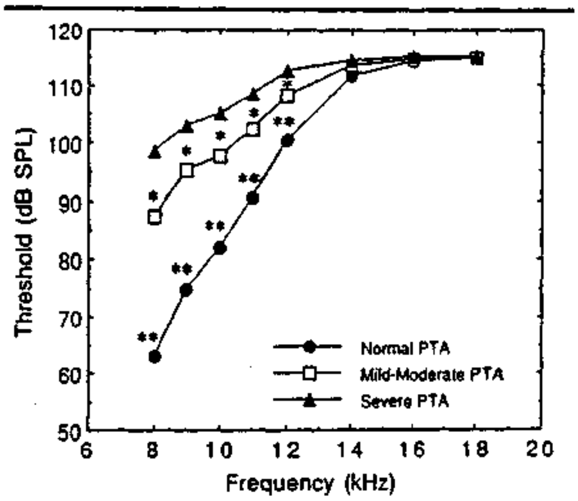


Fig (25): Mean EHF thresholds (dB SPL) for male and female listeners. Asterisks indicate statistically significant differences ($p < .05$).

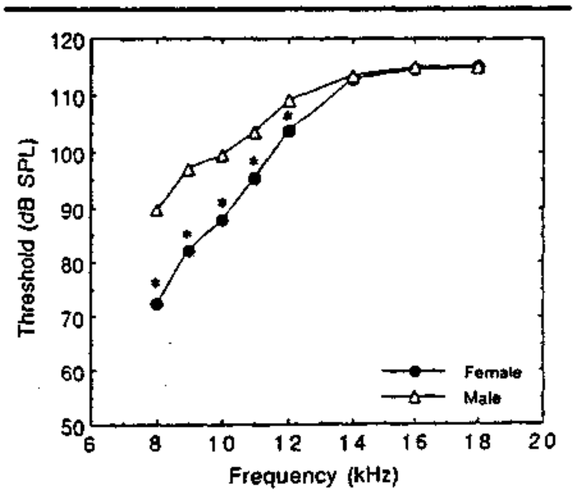


Fig 26: Mean EHF thresholds (dB SPL) for males and females in each of the three PTA groups (normal, mild-moderate, and severe groups in left, middle, and right panels, respectively). Asterisks indicate statistically significant differences ($p < .05$).

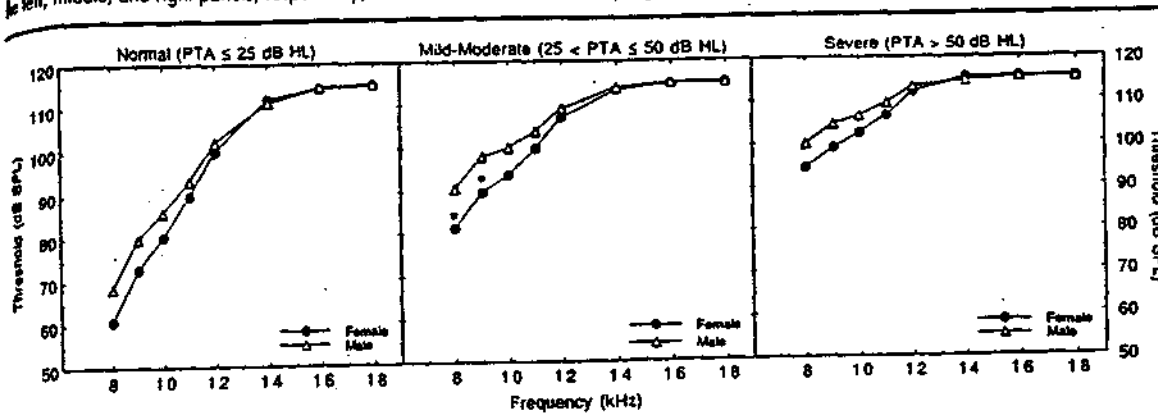


Table-14: The effect size Eta^2 of gender and PTA, in percent, EHF thresholds.

Frequency (kHz)	Gender	PTA	PTA/Gender interaction
8	2.7	33.0	0.1
9	3.0	26.4	0.1
10	2.1	21.0	0.1
11	1.3	16.4	0.0
12	0.6	14.2	0.0

Sakamoto, Sugasawa, , Kaga, , Kamio, (1998) measured the sound pressure level thresholds in the high-frequency range (8 to 20 kHz) in 25 non-hearing impaired young adults from 20 to 29 years of age. The thresholds increased gradually as a function of frequency. Two notable points were found

1. The threshold reached a plateau above 18 kHz
2. The threshold decreased slightly at 12 kHz

Fig. 27 shows that, as the subjects might respond to the low frequency noise of the stimulus wave, the threshold became a plateav above 18 kHz. An acoustic resonance in the ear canal caused the threshold to decrease at 12 kHz. The authors conclude that in clinical studies of extended high-frequency audiometry, the threshold data should be carefully evaluated above 18 kHz and at 20kHz.

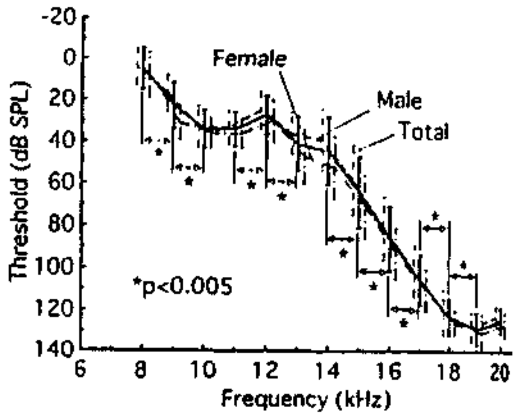
Sakamoto, Sugasawa, ., Kaga, Kamio, (1998) measured sound pressure threshold at the extended high-frequencies of 8 to 20kHz for 65 normal subjects aged between 10 and 69 years. The thresholds increased gradually as a function of frequency, except around 12 kHz and above 19 kHz and also a function of age. (Fig. 28 and Fig. 29)

To clarify the connections between threshold frequency and age, the authors introduced the regression lines for the threshold by analysing 2 ranges of frequencies (8-10kHz and 14-19kHz) and determining their slopes and intercepts. The regression line analysis revealed that the thresholds at 8-l0kHz tend to increase more at higher frequencies as subjects age increased above 30-39 years and those at 14-19kHz increased translationally with increase of age. (Fig. 30 and Fig 31).

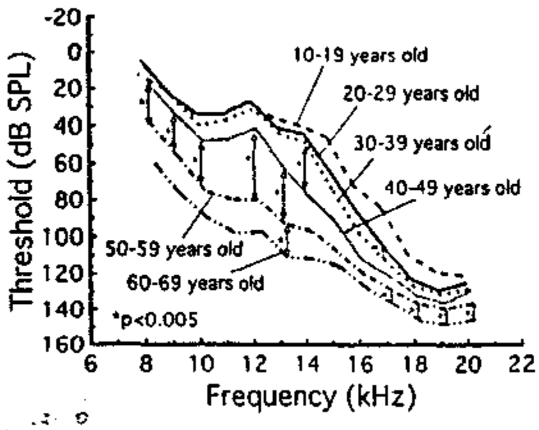
Gupta, Govil, , Saoji, , Binu, , Burman, 1 (1999) conducted a study to determines the feasibility of extended high-frequency audiometry using routinely employed procedures in clinical audiometry and the effect of aging on high-frequency.

Forty five subjects (90 ears) were evaluated in the age range of five to sixty five years having normal hearing sensitivity in the conventional (250 Hz-8kHz) frequency range. The subjects were divided into three age groups of 5-15 years, 20-40 years and 50 years and above. The GSI-61 clinical audiometer was used to obtain thresholds in the 8 to 20kHz range along with optional high-frequency earphones (Sennheiser HDA 200).

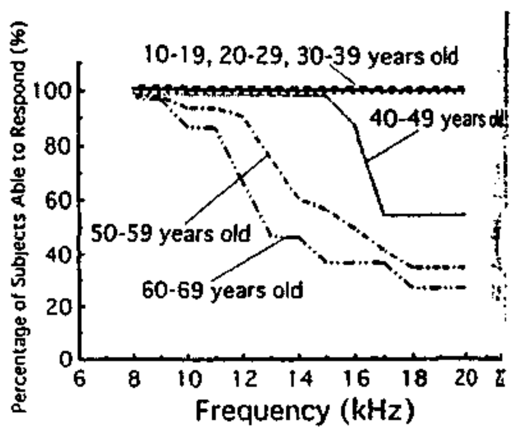
Results showed that although threshold increases monotonically as a function of frequency for all age groups, those increases does not necessarily represent hearing loss. Since no change was observed in thresholds for paediatrics (i.e., 5-15 years) and adults (i.e., 20-40 years) age group, it is reasonable to assume that hearing loss has not yet occurred in the 8 to 20 kHz frequency region within these age groups. Means and standard deviations of



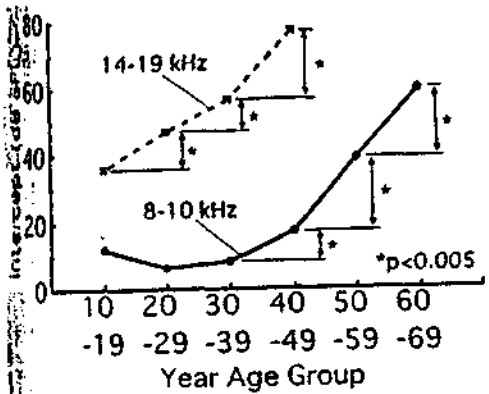
Fig(27): Average threshold of young adults.



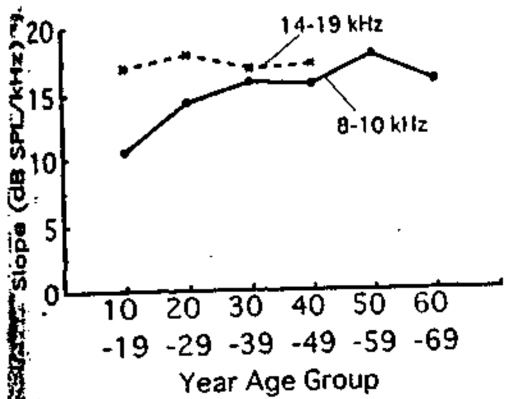
Fig(28): Average threshold (dB SPL) as a function of frequency (kHz) for the six age groups.



Fig(29): Percentage of total subjects (grouped by age in decade) able to respond to the extended high-frequency audiome survey.



Fig(30): Intercepts of the regression lines of the threshold as a function of age.



Fig(31): Slopes of the regression lines of the threshold as a function of age.

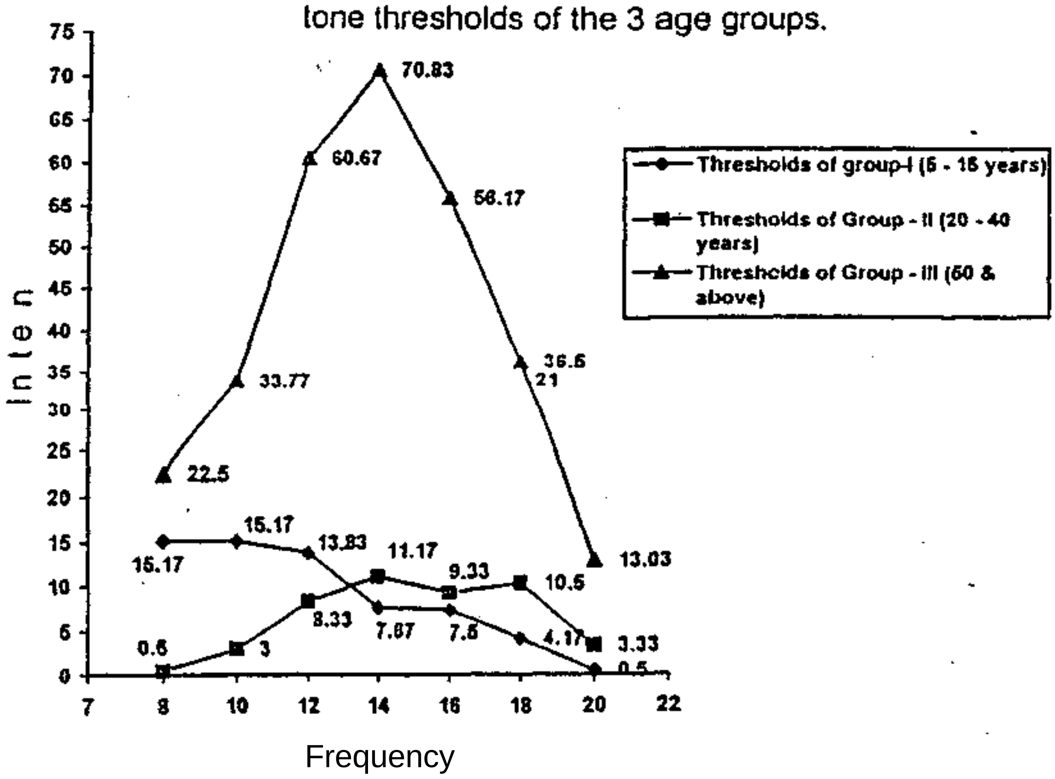
high-frequency pure-tone thresholds of three age groups are shown in Table (15).

Table 15 : Showing the mean and standard deviation of high frequency pure tone thresholds of the 3 age groups (Average of right and left ears.)

		8kHz	10 kHz	12.5kHz	14 kHz	16 kHz	18 kHz	20 kHz
Group -1 (5-15 yrs)	Mean	15.17	15.17	13.83	7.67	7.50	4.17	-0.50
	Std. deviation	5.65	6.09	5.52	5.68	9.98	13.78	10.37
Group -II (20-40 yrs)	Mean	0.50	3.00	8.33	11.17	9.33	10.50	3.33
	Std. deviation	9.04	12.08	12.34	13.94	11.87	11.62	9.47
Group - HI (50 &above)	Mean	22.50	33.77	60.67	70.83	56.17	36.50	13.03
	Std. deviation	7.85	16.92	17.60	11.30	4.86	4.94	4.17

Table (15) shows that there was a differences between the high-frequency pure-tone threshold of the three age groups. It showed that there was not much of differences between high-frequency puretone threshold of paediatric and adult age groups though the thresholds of paediatrics were better than adults. When the paediatrics and adults were compared with geriatrics there was a significant difference between high-frequency pure-tone thresholds. Large changes in sensitivity were apparent in the geriatric age group and these changes were apparent at all frequencies which is in contrary to the study done by Stelmachowicz et al (1989) Fig (32) showed that the loss of hearing sensitivity as a function of age was most rapid in the 12.5 to 18kHz range which was in accordance with the study done by M, Sakomoto et al (1998). Left and right ear of all age groups were also compared. Mean

Fig (32) : Showing the mean of high- frequency pure tone thresholds of the 3 age groups.



thresholds of the left and right ear are shown in Table (16). Table (16) shows that there was not much of significant difference of high-frequency thresholds of the two ears. Therefore the study revealed that as the age increases, there was decrease in the high-frequency pure- tone thresholds and are more significant in geriatric population. This could be attributed to the degeneration of inner and outer hair cells in the organ of corti, atrophy of the spiral ganglion and disappearance of the neurons in basilar membrane, hyper-trophy and hyaline degeneration of the basal part of the basilar membrane.

Table (16) : Showing the mean thresholds of Right and Left ear of 3 age-groups

		8kHz	10 kHz	12.5kHz	14 kHz	16 kHz	18kHz	20 kHz
Right ear	Mean	11.33	15.22	25.67	31.56	22.56	16.00	3.24
Left ear	Mean	14.11	19.40	29.56	28.22	26.11	18.11	5.13

EQUIPMENTS AND ACCESSORIES

This chapter deals with the instruments (audiometers, transducers etc), that have been developed or tested during the years 1988-1998 for measuring high-frequencies. It mainly deals with the studies conducted with the instruments in order to find the reliability of the instrument or a comparison between two instruments (transducers).

Stemachowicz, , Beauchaine, , Kalberer, , Langer, and Jesteadt, (1988) designed a study to evaluate both intra - and intertester reliability of auditory thresholds in the 8 to 20 kHz range using a high-frequency audiometer developed by Stevens et al (1987). This audiometer incorporates an indirect measure of the SPL at the medial end of the ear canal for frequencies from 8,000-20,000Hz. Here the signals from a high-frequency transducer are introduced into the ear canal via a plastic tube. The measurement of SPL is made in an earpiece at the end of this tube at some distance from the tympanic membrane, and a correction alogorithm is used to calculate the sound pressure at the medial end of the ear canal. Because this calibration procedure takes into account any individual differences in ear canal geometry and size, this approach may provide a more accurate representation of the SPL at the medial end of the ear canal for individual listeners than other methods.

In the study, 20 normal hearing subjects (10 males and 10 females) ranging in age from 21-57 years were taken. The results suggested that the reliability of threshold estimates decreased as a function of frequency. In the higher frequencies, accurate calibration functions could not be obtained for many subjects. In these cases, values extrapolated from lower frequencies were used to estimate SPL. Fig II (1) shows that extrapolation will be necessary at some frequencies for most subjects.

It is possible that increased experience with the device might improve the quality of calibration functions and subsequently increase the upper frequency limit across subjects, reducing the extrapolation problem. This in turn might improve reliability in the higher frequencies.Inter- tester variability was only slightly higher than intra-tester variability.

Findings reveal that the standard error of measurement for both intra-and intratester measures increases as a function of frequency (Fig II (2)) The use of circumaural earphones or traditional insert earphones may not be as reliable in the higher frequencies. (Table II (1).

Table-II(l): Standard errors of measurements (S) for test- retest data. The present study represents data from 20 listeners obtained using TDH-39 erphones and a standard audiological procedrue. Hie Marshall and Gossored (1982) study represents data from 20 ears using a similar transducer in procedure.

Frequency (kHz)	Present Study	Marhsall and Gossman (1982)
0.25	2.1	4.1
0.50	2.1	2.9
1.00	2.1	3.2
2.00	2.4	3.9
3.00	—	3.2
4.00	2.7	3.4
6.00	—	6.3
8.00	3.2	5.5

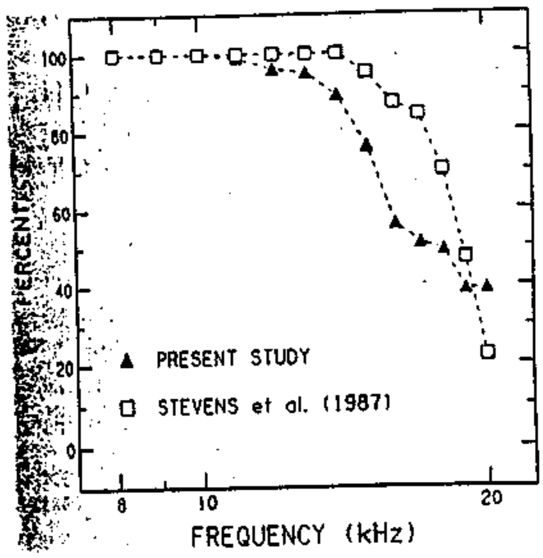


Fig II (1): Percent of ears for which valid calibration function could be obtained up to the frequency noted on the abscissa. Filled triangles are from the present study and the open squares represent data from Stevens et al (1987)

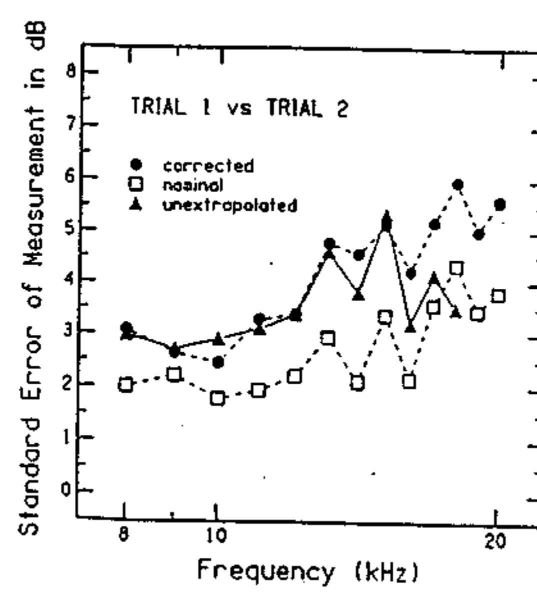


Fig II (2): Standard error of measurement (in dB) as a function of frequency. Data represent intratester reliability, and error variances have been pooled across the two examiners. Filled circles represent the corrected values, open squares represent the nominal attenuator settings, and filled triangles represent a subset of corrected values when extrapolation was unnecessary. Due to the reduction in N as a function of frequency, extrapolated data points are omitted for the highest two frequencies.

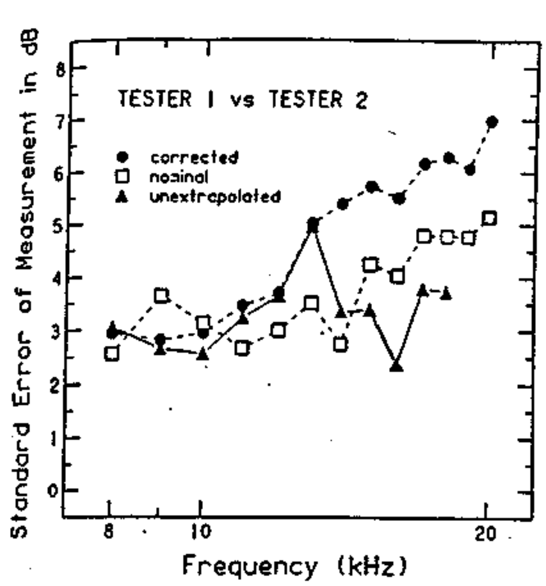


Fig II (3): Same as Fig II (2), except for intertester reliability.

Most importantly, it is pointed that even though test-retest reliability is poorer for the corrected values than for the nominal attenuator values, only the former are presumed to be an estimate of threshold SPL. Table 11(2) and Fig 11(3).

Table-II(2): Comparison of reliability of thresholds, earpiece fitting, and calculation of caliberation values estimated from 1-month test- pretest data obtained in the present study and by Green et aL (1987)

	Estimates of S				Derived s.d.		
	n	SPL	Att	Cor	T	C	F
Present study (within testers)							
8-14 kHz	123	3.4	2.3	2.7	2.2	2.6	0.6
15-20 kHz	23	3.7	3.8	3.0	3.1	2.0	2.2
Present study (across testers)							
8-14 kHz	123	3.5	3.1	2.7	2.7	2.2	1.6
15-20 kHz	23	4.4	4.3	3.1	3.8	2.3	2.2
Green et al. (1987)							
8-14 kHz	119	2.5	2.3	2.1	1.9	1.6	1.3
15-20 kHz	109	4.6	4.2	3.4	3.7	2.7	2.0

Variability threshold estimates in dB SPL was higher than that observed for the uncorrected attenuator settings. Exclusion of extrapolated values improved reliability substantially.

Stelmachowicz, ., Beauchaine, , Kalberer, Kelly, . and Jesteadt, W. (1989) compared the reliability of the high-frequency audiometer (Stevens et al 1987) with a less complicated system that uses supra-aural earphones (Koss system). The new approach permits calibration on an individual basis, making it possible to express thresholds at high-frequencies in dBSPL. Data obtained from fifty normal hearing subjects, ranging in age from 10-60 years, were used to evaluate the effects on reliability of threshold variance, earpiece/earphone fitting variance and the variance associated with the high-frequency audiometer calibration process. In order to provide the appropriate corrections to express the high-frequency audiometry data in dBSPL, a calibration function was obtained prior to and following each set of threshold estimates. Thus an initial calibration function was obtained and thresholds were established using each procedure. Then a second calibration function was obtained and a second set of thresholds was measured without moving the ear piece. Following this, a third calibration function was calculated . A set of thresholds also was obtained after replacement of the ear-piece. For this latter condition, a calibration function was obtained before and after thresholds were assessed. The mean of the functions obtained prior to and following each set of thresholds was used to provide the correction factors for a particular set of threshold estimates. The order in which these nine sets of thresholds were obtained was counter-balanced across subjects. For each set of high-frequency audiometry thresholds, nominal attenuator values and correction values were determined and individually determined correction values were added to the nominal values to yield estimation of threshold in dBSPL.

Without earpiece/earphone replacement, the reliability of thresholds for the two systems was similar. With replacement, the high-frequency audiometer showed poorer reliability than the Koss systems above 11kHz, largely due to errors in estimating the calibration function. High-frequency audiometry reliability was greater for subjects with valid calibration functions over the entire frequency range. Analysis of thresholds as a function of age revealed systematic increases in thresholds as a function of frequency in all age groups. In general, thresholds increased as a function of increasing age. Use of the Koss system to estimate high-frequency audiometry SPL thresholds for individual subjects introduced errors significantly larger than those encountered within repeated estimates of the high- frequency audiometry SPL thresholds. Koss thresholds, although more reliable within subjects, do not accurately reflect differences across subjects. The authors concluded that the benefit of being able to express thresholds at high frequencies in dB SPL must be weighed against the additional source of variability introduced by the high-frequency audiometry calibration process.

Thornton,A.R-D, Bell.I.E and Phillipps.J.J. (1989) evaluated the use of electro stimulation audiometer in monitoring hearing in the following areas :- (1) The variability and repeatability of threshold measures (2) To see if the instrument could be used on the ward where the patient would have to wear ear plugs to attenuate back ground noise, the effect of occluding the ears was assessed. (3) The applicability of the instrument to the range of patients in whom monitoring would be appropriate, specifically the relationship between the patients age and the effective upper frequency limit of the audiometer (Electro - stimulation audiometry can provide high-frequency bone - conduction threshold measurements). Eight normally hearing subjects, with ages for 20 to 42 years at 0.5, 1, 2, 3, 4, 6, 8, 12, 16 and 20 kHz were taken for this study. The measurement were obtained with the ears unoccluded and with both ears occluded by ear plugs. To examine the effects of age, 15 normally hearing subjects with out any history of audiological or otological abnormality were tested. Thresholds were measured at 1, 2, 4, 8 kHz and at 1kHz intervals from 9 to 20 kHz.

The data showed a variability in threshold measurement that is quite comparable with that obtained with conventional audiometry but which became smaller at frequencies of 12kHz and higher. There was no over all effect on the threshold of occluding the ears, which meant that the instrument can be used to monitor a non-isolated environment such as a ward. The effective cut off frequency was about 9kHz for patients aged 55 years, and so the use of an electro-stimulation audiometer to monitor high-frequency auditory thresholds is restricted to younger patients. The variability of the within-subject data is similar to that obtained with conventional audiometry. The largest differences for occlusion effect occurred at 500Hz (7.4 dB) (P> 0.02). (Fig II(4) Fig II(5), Table II(3), Table II (4). Inter-subject s.d. calculated from the mean values of the replicate measures at each frequency for the occluded and unoccluded conditions. Summary of the main effects of an analysis of variance. Significant effects are found for subjects and test frequency.

Table-II(3): Inter-subject s.d. (dB)

Frequency (kHz)	0.5	1	2	3	4	6	8	12	16	20
Occluded	4.6	5.0	3.9	5.7	3.5	5.5	7.2	5.7	9.4	4.5
Unoccluded	5.6	9.4	6.5	6.0	5.1	6.1	6.9	7.9	11.8	1.2

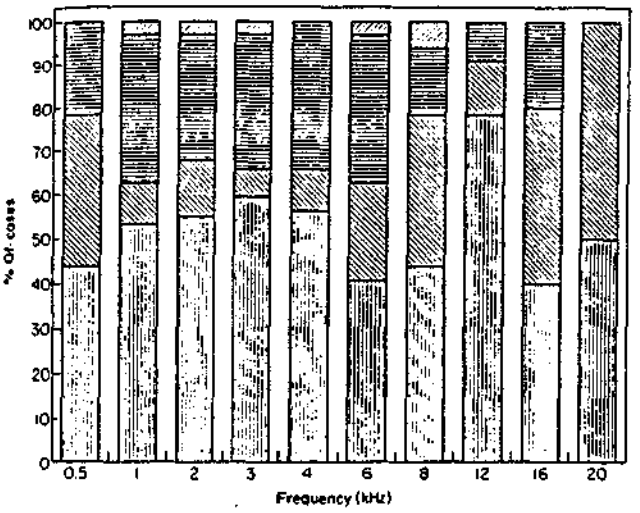


Fig II(4): *Test–retest differences combined for the occluded and unoccluded conditions. The differences have been split into 5 dB bins and the percentage of the sample having differences within each of the 5 dB bins is shown for each frequency.* ▨, 15–19.9 dB; ▤, 10–14.9 dB; ▩, 5–9.9 dB; □, 0–4.9 dB.

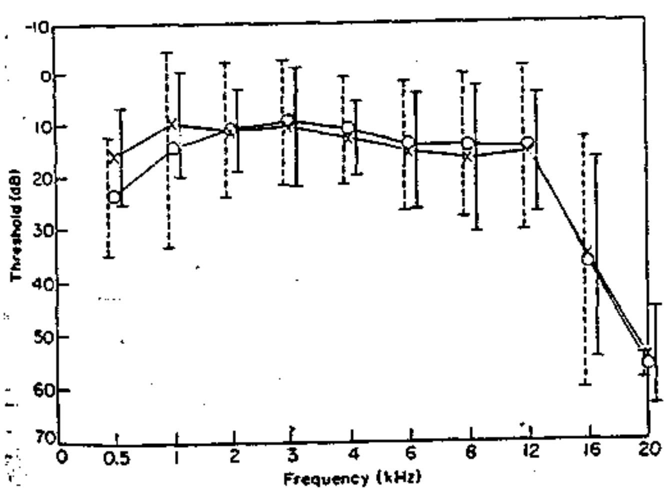


Fig II (5): *Mean thresholds at each frequency for the occluded and unoccluded conditions. The 95% confidence limits are also shown. The confidence limits for the unoccluded data are indicated by dashed lines to the left of the datum and those for the occluded condition are indicated by solid lines to the right of the datum. The ordinate is dB on an arbitrary scale, taken from Figure 1.* ×——×, *occluded*; ○——○, *unoccluded.*

Table-II(4): Analysis of variance.

Source of variation	Sum of squares	DF	Mean square	F	Significance of P
Main effects	38724.4	19	2038.1	47.3	<0.0005
Occluded/ unoccluded	10.8	1	10.8	0.3	N.S.
Frequency	36585.9	9	4065.1	94.4	<0.0005
Subjects	6229.5	7	389.9	20.7	<0.0005
Replicates	20.1	4	10.0	0.2	N.S.
Explained	38624.4	19	2038.1	47.3	<0.0005
Residual	17271.9	409	43.1		
Total	55995.9	420	133.3		

Hallmo. ., Sundby, , Mair, (1991) investigated the various response characteristics of the Pracitronic KH70 bone vibrator in the frequency range 0.25 through 16kHz. Masked threshold reproducibility was satisfactory throughout the frequency range. An occlusion effect was present only at frequencies at and below 1kHz. Stimulus perception was lateralized to the occluded ear through 1kHz and less consistently at successively higher frequencies. The KH70 does not satisfy the IEC 645 (1979) criterion for acoustic radiation for frequencies below 6 kHz, especially at the intermediate frequencies of 0.5,1 and 2 kHz. With the restrictions inherent in the occlusion effect, this does not, however, interfere with threshold determination. The vibrator thus seemed suitable for clinical use through 16kHz.

Lopponen,. Laitakari, Sorri, (1991) measured the skill vibrations induced by an electrical high-frequency audiometer (Audimax 500) with a sensitive accelerometer in five subjects. The measurements included the maximum output levels, the equivalent threshold force level (ETFL) decreases, the distortions over the whole frequency range (0.5-20 kHz) of the audiometer and the effect of different electrode positions. The results showed that there is a real bone-conduction effect with this audiometer throughout the high-frequency range with the different electrode positions. The mean maximum output level ranged between 60 and 70 dB ETFL in the high-frequency range. The ETFL decrease was of the same order, irrespective of the frequency, but the differences in the maximum output level at different frequencies necessitate a frequency-dependent additive correction so that the equal hearing level at each frequency can be achieved. When the electrodes were placed on both mastoids, the second harmonic distortions were found only at signal frequencies of 2 and 4 kHz. At the electrode positions the distortions were increased, however not being audible.

Hansen, , Brask, and Larsen, (1993) tested a new circumaural transducer in the frequency range 125 Hz to 20kHz. The test equipment is constructed around a Bruel and Kjaer heterodyne analysator / BFO 2010(beat frequency oscillator) (Bruel and Kjaer co, Naerum, Denmark) and an associated control box (Fig II(6).

The BFO in the 2010 (2) generates the sinusoidal signals used for the test and it is controlled by a variable voltage (3A) which is generated in the control box (3). The voltage can be adjusted is 23 discrete steps by which 23 discrete frequencies in the range from 125Hz to 20kHz can be generated. The test signal is led from the 2010 to the control box, which contains a switching circuit (3B+C) making it possible to present the signal for the test person with a suitable rise and fall times. This is followed by a 1 dB

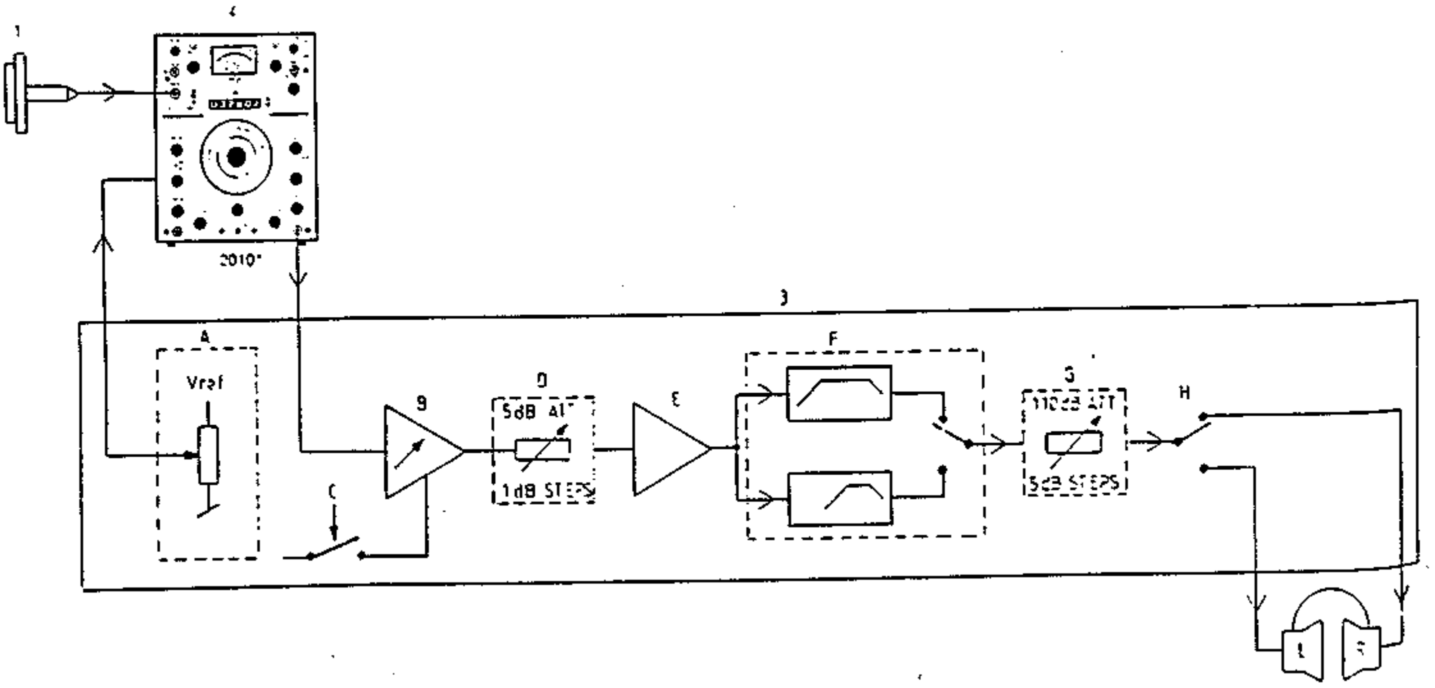
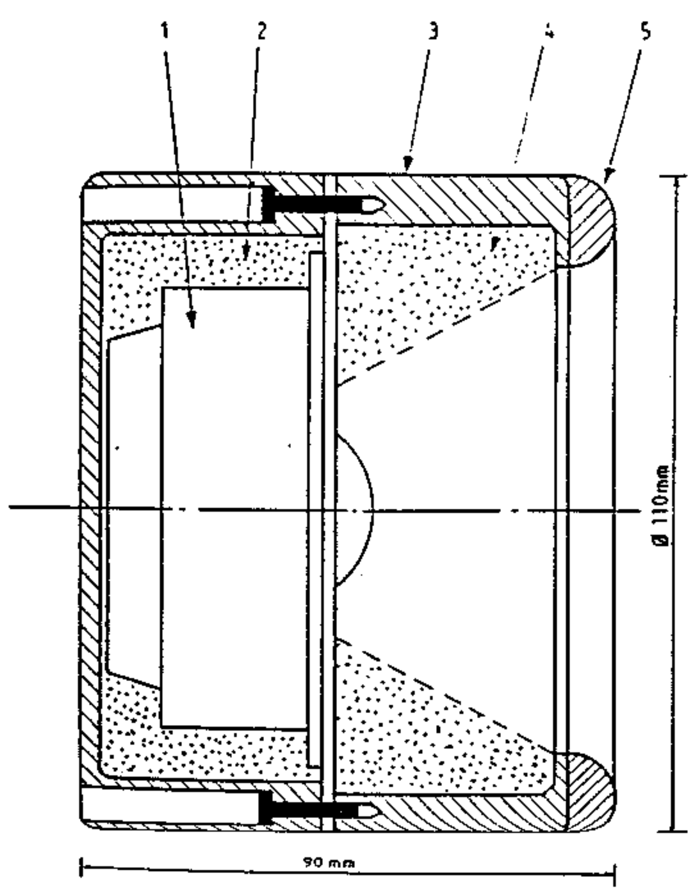


Fig II(6) : Modular schematic drawing of instrumentation set-up. See text for details.



figII(7) Sketch of the transducer diagram. Weight apptoximately 900 g. See text for details.

attenuator (3D) making it possible to attenuate the signal withing a 5 dB range, after which discreetly constructed power amplifier (3E) boosts the signal upto suitable output level. Following this, the signal is high pass filtered with a choice of two cut off frequencies (3F) at approximately lOOHz. At test frequencies above 13kHz, the high pass filter with the cut off frequency at 12kHz is switched on. This is done to ensure an optimal signal-to-noise ratio by testing at very frequencies as the ear has a very low sensitivity at high-frequencies. A passive constructed attenuator (3G) with a dynamic range of 110 dB -in 5dB steps is used to regulate the test signals, so an output range of-10 to 100 dS SPL in 5 dB or ldB steps is obtained after calibration. An output switch (3H) conducts the signal to the left or right ear phone.

The transducer system (Fig II 7). consists of two identifically constructed head phones. The single headphones is constructed around a 1" dome tweeter (Dynaudio Co., Skanderborg, Denmark) (i) with a large dynamic range and a broad frequency range (-3dB point approx. 22 kHz measured under free-field condition). The dome tweeter is mounted inside a shell (3) in which damping material (fiber cotton) is placed in front (4) of as well as behind (fiber cotton) is placed in front (4) of as well as behind (2) the loudspeaker. The head phone is also equipped with a "soft" ear cushion (5) which provides a pleasant and sound proof connection with the subjects head. The relatively large mechanical mass of the shell and the damping material provide a good damping of back ground noise at both low and high-frequencies. The volume (approx. 120cm) which the shell, the loudspeaker and the damping material make in front of the ear is constructed so that the

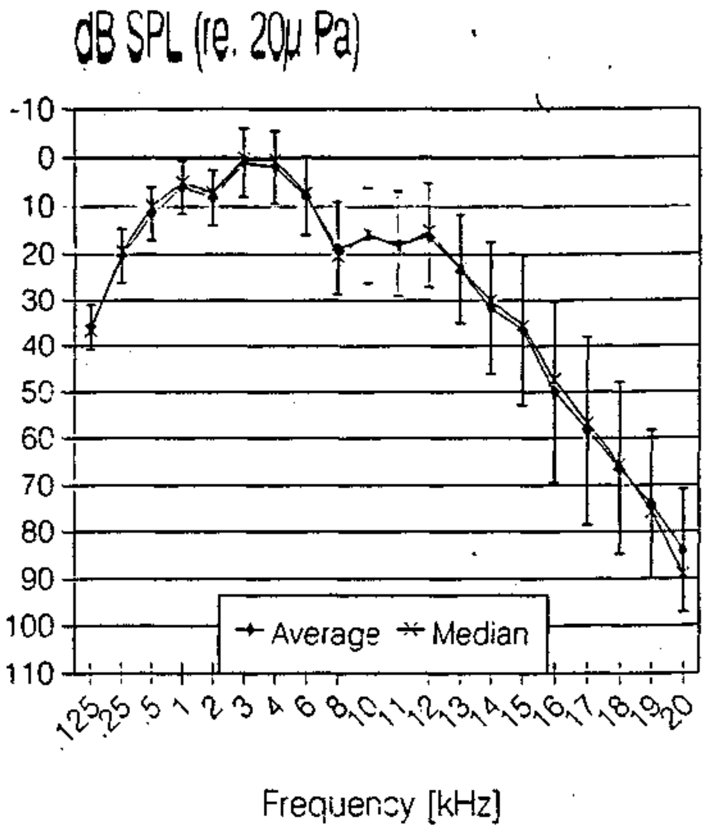
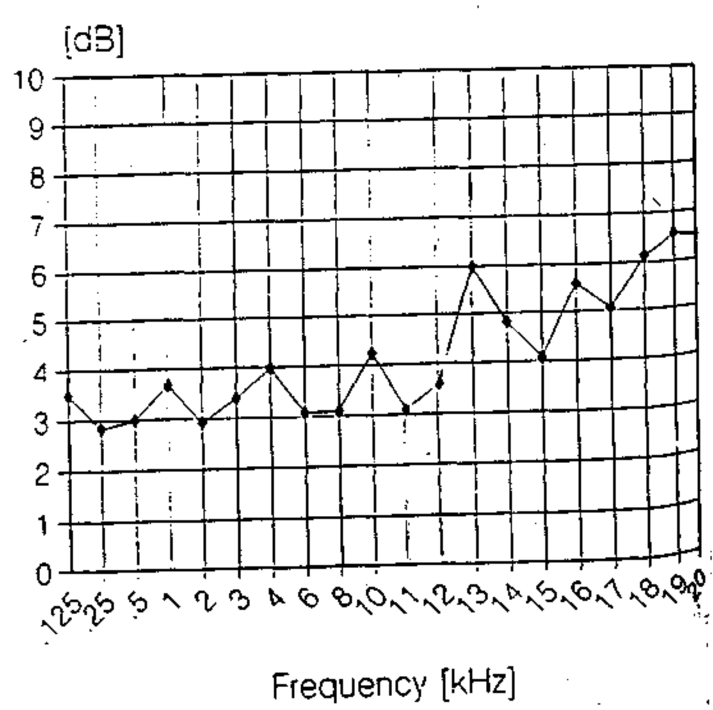


Fig II (8) : Average with standard deviations and median threshold values obtained with a new low acoustic impedance transducer system. Normal threshold values for 57 individuals (age range 10-20 years). The X-axis is non linear.

Fig II (9) : Test-retest standard deviation from 12 inexperienced persons (24 ears). The range of standard deviations is from 2.8 to 6.6 dB. The X-axis is non-linear.



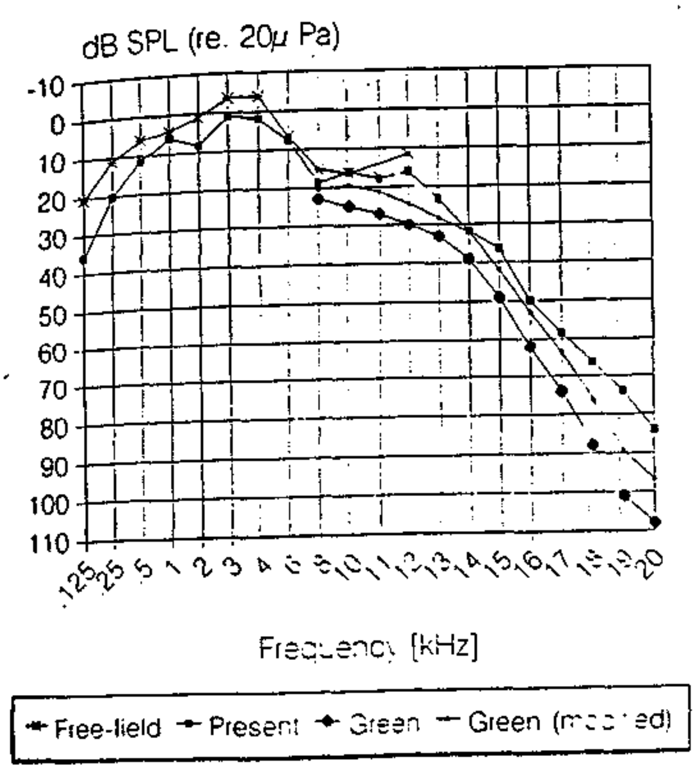


Fig II (10) : Comparison of normal average values obtained by Green and the present study. International standard for free field threshold (ISO 226) is also shown. As can be seen, there are only small differences between the present study and the modified Green values and free-field values. The X-axis is non-linear.

ear is loaded closely to free field conditions, whereby the transfer function of the ear canal is not being significantly influenced. The construction of the headphone also ensures that the sensitivity to different positions around the ear is reduced compared to conventional audio-metrical headphones, because this transducer has low acoustic impedance and loads the ear closely to free field conditions.

This transducer was tested by the authors mentioned above on 57 individuals (114 ears) in the age range of 10 to 20 years (median age 17.0 years).The results showed a fairly good accordance with the ISO standard free field threshold values and seemed to confirm that the new transducer system loads the ears similarly to free field conditions. The results were also compared with the threshold values from other high-frequency investigations using different transducer systems. In order to verify the reliability of the system, a test retest was carried out on 12 inexperienced normal individuals. The standard deviation of the test retest ranged from 2.8dB to 6dB. (Fig II(8), FigII(9),FigH(10).

Han, and Poulsen, . (1998) had determined equivalent sound pressure levels (ETSPLS) for the Sennheiser HDA 200 earphone and the Etymotic Research ER-2 insert earphone. 31 test subject participated in the measurements. The ETSPL measurements were performed at frequencies 125Hz and 16kHz (Fig II(11). The results are shown in fig II (12), Fig II(13), and Tab II (5), Tab II (6)

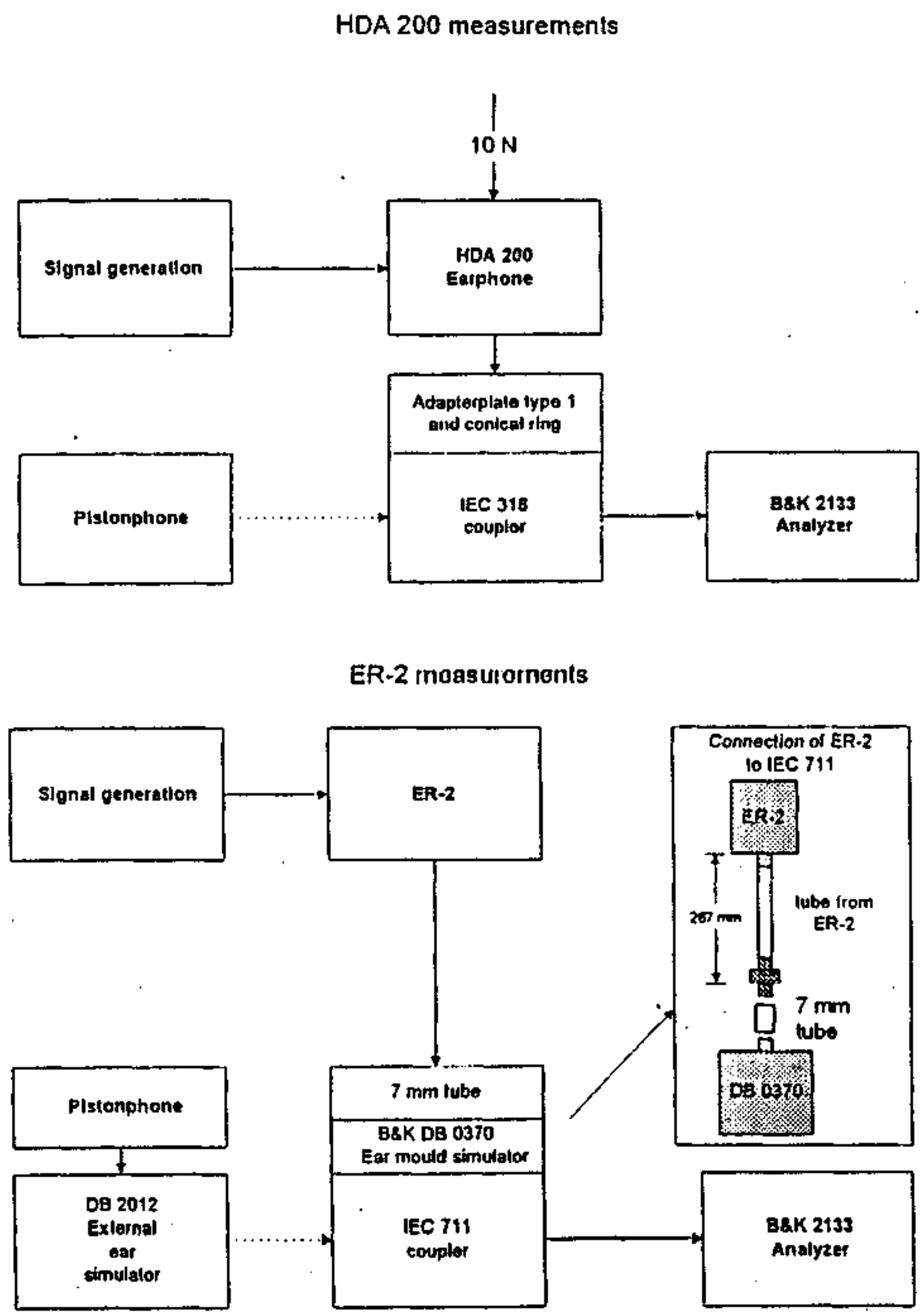


Fig.III(11) Block diagram of calibration measurements.

Table 11(5): Main data for HDA 200

	Medium	Mean	Sd	Left	Right	Male	Female	18-21Y	22-25Y
125	30.8	31.0	4.1	31.0	31.0	30.4	31.8	31.3	30.8
250	18.0	18.8	4.2	18.6	19.0	18.7	18.9	18.8	18.9
500	9.5	9.9	4.3	10.4	9.4	10.4	9.4	9.7	10.2
750	5.7	6.0	4.5	5.9	6.2	6.2	5.8	5.9	6.2
1k	5.3	5.1	3.7	5.6	4.5	5.3	4.9	5.3	4.9
1.5k	4.3	4.6	4.7	4.6	4.6	4.5	4.7	4.5	4.6
2k	4.3	4.2	5.1	5.1	3.3	3.3	5.3	3.4	5.0
3k	1.8	1.8	4.8	2.5	1.1	2.5	1.1	1.0	2.8
4k	8.5	8.8	5.2	8.6	9.1	10.2	7.2	8.9	8.8
6k	18.7	18.5	6.4	17.9	19.6	19.4	17.2	18.7	18.2
8k	21.0	21.0	5.9	22.1	19.8	21.5	20.4	20.0	22.0
9k	20.4	19.6	5.2	20.3	18.8	19.5	19.5	18.8	20.4
10k	21.3	21.0	7.3	20.2	21.7	23.0	18.5	20.5	21.5
11.2k	22.2	23.2	7.1	22.7	23.8	25.0	21.1	23.4	23.1
12.5	26.5	27.7	7.9	26.5	28.8	29.9	25.0	28.2	27.0
14k	36.3	38.4	12.3	38.9	38.0	42.3	33.9	41.0	35.6
16k	62.7	62.6	16.8	61.2	63.9	63.2	61.8	64.8	60.1
N	62	62	62	31	31	34	28	32	30

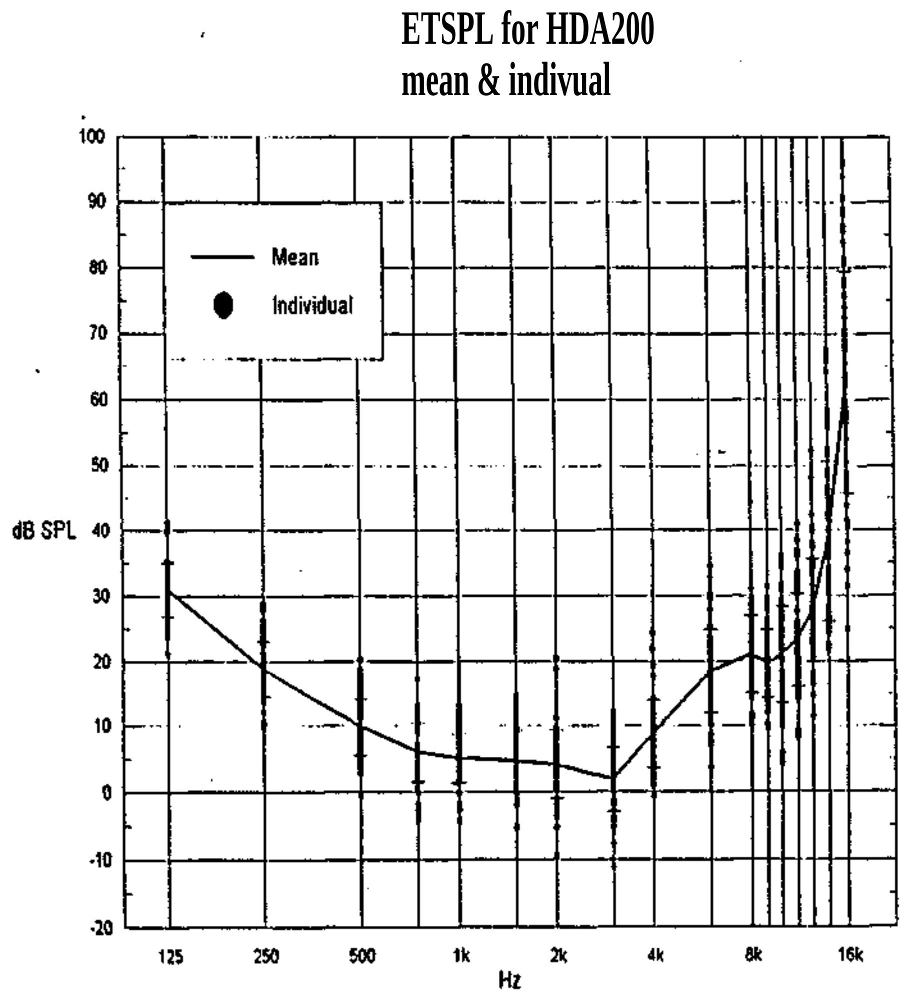


Fig II (12): ETSPL for HDA 200. Mean, standard deviation and individual data.

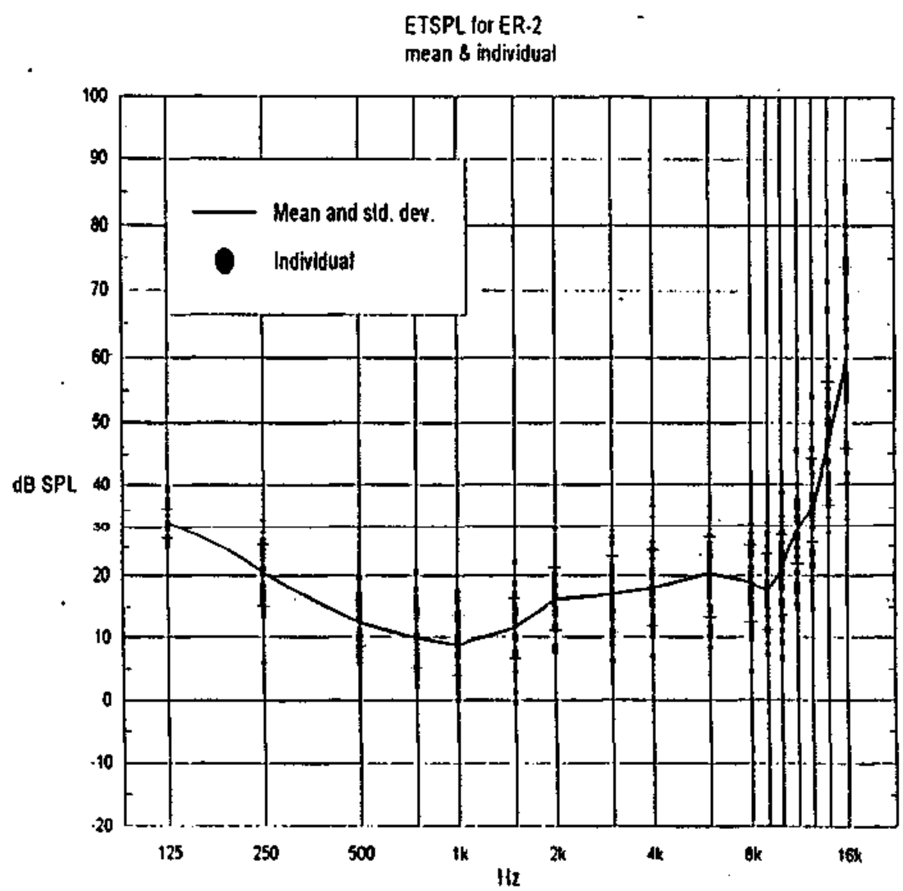


Fig II (13): ETSPL for ER-2. Mean, standard deviation and individual data.

Table 11(6): Main data for ER-2

	Medium	Mean	Sd	Male	Female	18-21Y	22-25Y
125	30.1	31.3	4.0	32.3	30.1	31.1	31.5
250	21.0	20.4	5.3	21.7	18.8	19.3	21.6
500	12.7	12.3	3.7	13.5	10.9	12.8	11.8
750	9.0	9.8	4.7	10.5	9.0	9.5	10.2
Ik	9.2	8.8	4.8	10.2	7.1	8.7	8.9
1.5k	12.9	11.5	4.8	11.5	11.5	11.3	11.7
2k	15.3	16.1	5.0	17.3	14.7	15,2	17.1
3k	16.2	16.9	6.1	18.8	14.7	15.5	18.5
4k	17.1	18.0	6.2	20.3	15.3	16.9	19.2
6k	20.1	20.3	7.0	22.3	17.8	19.1	21.5
8k	18.8	18.8	6.4	19.4	18.1	17.8	19.9
9k	15.8	17.4	6.1	19.1	15.3	17.0	17.8
10k	21.0	20.6	7.1	23.8	16.7	19.0	22.3
11.2k	30.5	28.9	7.2	32.1	25.1	27.7	30.3
12.5	34.9	35.1	9.2	38.8	30.6	34.8	35.4
14k	44.0	46.3	10.2	50.5	41.1	45.0	47.5
16k	56.8	59.8	13.9	61.6	57.8	60.2	59.4
N	31	31	17	14	16	15	

Data for HDA 200 are found in Richter (1992 and 1993) Only at 6 and 8kHz do the data deviate from the data presented in this study. The deviations are reduced to 2dB and 3dB respectively when no reference is made to DT 48 measurements (Richter 1997). Data from Takeshima et al (1995) show deviations at 6kHz (5dB) and at 8kHz (7dB). All three sets are in agreement above 10kHz (Fig 11(14). The frequency characteristics of HDA 200 is very smooth and does not seems to be responsible for the variations. It seems like that the 6 and 8 kHz variations could be caused by critical geometrical

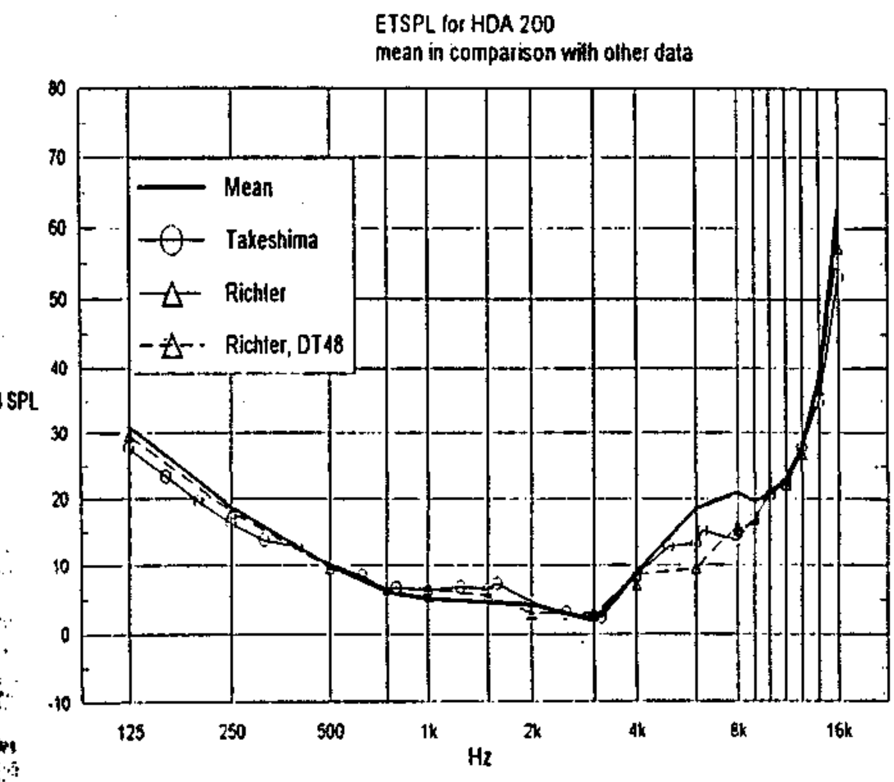


Fig II (Mean values from the present investigation compared data from other investigations. Data from Takeshima cover the frequency range 125 Hz to 16 kHz. The data called Richter cover the frequency range 8 kHz to 16 kHz. The data called Richter DT 48 cover the range 125 Hz to 8 kHz and are referred to threshold measurements using the Beyer DT 48 earphone.

interactions between the subjects ears and the HDA 200 earphones Han, and Poulsen, (1998) recommended using the average of three investigations for audiometer calibration to the *HDA* 200 earphone (Tab 11(7). The RET SPL data for ER-3 are generally 2-3 dB below the mean values ER-2 found here.

Table 11(7): The average ETSPL data may be recommended as future reference vales for HDA 200

	Richter	Takeshima	This investment.	Average
125	29.5	27.6	31.0	29.4
250	18.0	16.3	18.8	17.7
500	9.5	10.2	9.9	9.9
750	6.5	6.5	6.0	6.3
1k	5.5	6.2	5.1	5.6
1.5k	5.5	6.4	4.6	5.5
2k	3.0	4.7	4.2	4.0
3k	3.0	2.5	1.8	2.4
4k	7.1	8.4	8.8	8.1
6k	9.5	13.2	18.5	13.7
8k	15.2	13.8	21.0	16.7
9k	16.8	17.1	19.6	17.8
10k	21.5	20.5	21.0	21.0
1.2k	22.1	22.3	23.2	22.5
12.5	26.7	27.7	27.7	27.4
14k	36.8	34.8	38.4	36.7
16k	57.3	53.2	62.6	57.7
N	28	24	31	

MASKING

Two functionally equivalent cochleae can be expected to contribute equally to high-frequency bone-conduction threshold measurement if an acoustic signal is delivered with the same force level at each cochlea. Theoretically, an unmasked bone-conduction threshold would be 3dB more sensitive than a monaural threshold due to binaural summation. Previous studies assessing equivalent high- frequency threshold force levels have not prevented the non- test ear from participating in the threshold measurement (Richter and Frank, 1985, Frank and Ragland,1987). A reliable masking technique is necessary for the determination of puretone thresholds in the high-frequency (HF) range in patients with symmetrical hearing loss. Knowledge of the interaural attenuation for these high frequencies, greater than 8kHz for air-conduction and greater than 6kHz for bone- conduction is a prerequisite. Interaural attenuation for AC signals in the frequency range above 8kHz has earlier been reported for the Koss HV/1A earphone (Rappaport et ai, 1982).

Mc Dermott, Fausti, Henry, Frey, (1990) reported the effects of contralateral masking on high-frequency threshold force levels. 28 subjects of age range 21 to 49 years (25 Females and 3 Males) with mean age of 30.1 years of age and negative histories of otological disorder and symmetrical binaural hearing were measured for high- frequency air-conduction and bone-conduction thresholds with a high-frequency auditory evaluation system using matched Koss HV/1A earphones and Pracitronic KH70/5 bone vibrator. Measurements were made for both unmasked and masked bone-conduction thresholds at the ipsilateral mastoid of the better ear.

The contralateral masked condition was performed using 30dB SL 400Hz narrow band masking noise centered at frequency of test tone.

Table 111(1) shows the mean, SD and mean differences between high-frequency air-conduction threshold for the test and non-test ears among the 28 subjects. For frequencies 6-12 kHz the mean interaural differences ranged between 0 and 5.9dB.

Table-III(l): Means, standard deviations and mean differences between high-frequency air- conduction thresholds for the test and nontest ears in 28 normal hearing subjects

Ear	High-frequency air-conduction **thresholds**					
	6kHz	8kHz	9kHz	10kHz	11kHz	12kHz
Better ear						
Mean	23.9	27.9	30.9	32.5	36.7	39.7
Sd	14.7	13.7	11.0	14.0	18.4	21.7
Poorer ear						
Mean	23.9	22.7	29.3	30.0	32.5	33.8
Sd	13.0	10.2	11.0	14.0	14.9	16.6
Difference	0	5.2	2.5	2.5	4.2	5.9

Table-III(2): Means, standard deviations and mean differences between high-frequency threshold force levels for the masked and unmasked conditions in 28 normal hearing subjects.

Ear	High-frequency air-conduction thresholds					
	6kHz	8kHz	9kHz	10kHz	11 kHz	12kHz
Masked						
Mean	35.9	35.2	37.9	38.6	40.0	42.9
Sd	7.3	8.3	9.1	9.8	12.2	16.2
Unmasked						
Mean	33.7	33.4	36.2	36.5	38.5	39.5
Sd	7.7	8.3	9.2	10.5	12.7	12.8
Difference	2.2	1.8	1.7	2.1	1.5	3.4

Table III(2) shows the mean threshold force levels for the unmasked and the masked conditions. Mean bone-conduction thresholds for both masked and unmasked conditions ranged from 33.4 and 42.9 dB force level for frequencies 6-12 kHz. Mean differences between masked and unmasked conditions ranged from 1.5 and 3.4 dB with a mean difference across frequencies of 1.8 dB. The differences among the two high- frequency threshold force level measurements were statistically significant. The results demonstrated that masked high-frequency bone -conduction thresholds were 1.5 to 3.4 dB poorer than the unmasked thresholds and that these differences were statistically significant at the 0.01 level of confidence except at 12 kHz. The study supports the need to use effective contralateral masking to eliminate cross hearing in investigation of high-frequency bone-conduction threshold measurements. The interaural attenuation of the earphone used in this study, the Koss HV/1A earphone, is at least 30dB and independent of frequency for the range of 8 through 20kHz (Rappaport et al, 1982).

Löppönen, . (1992) evaluated the possibilities of masking the electric bone-conduction (EBC) signals with white noise and developed a monaural test method. He took two study groups. The study group (1) contained eight unilaterally deaf subjects (three males and five females) of mean age 17 years (9-44 years). None of the subjects had conductive hearing loss. The study group (2) had 104 young subjects (63 males and 41 females) of mean age 20 years and age range 9-27 years with no conductive hearing loss for normative data. Madsen 0B822 audiometer and Audimax 500 audiometer with Mylar coated electrodes placed on the mastoid of the test ear and on the ipsilateral thenar eminence. In the second study, the thresholds were measured with the electrode, placed on three different sites. 1) binaurally, the electrodes on both mastoids 2) and 3) monoaurally (both ears separately) one electrode on the mastoid and the other on the ipsilateral thenar prominence. Sony MDR-V4 dynamic earphones were placed supra aurally on both ears during the measurements with and without masking. The results showed that the electric bone-conduction signals can be masked with air-conduction signals and thus electric bone-conduction measurements reflect monaural thresholds. The minimum masking level was 50-60 dB SPL in the high-frequency range [Fig.III(l), Fig. III(2), Fig. III(3), Fig. III (4)].

There was no cross hearing products in the high-frequency range with the earphones used. At the frequencies 0.5 -14kHz, the better ear's masked electric bone-conduction threshold were on the average 2.6 dB (range 0-4.5 dB) poorer, compared with the binaural electric bone-conduction thresholds indicating a binaural summation effect. The results confirm that the electric bone-conduction thresholds can be measured monoaurally if the contralateral ear is masked. Because the dynamic range of the electric bone-conduction audiometer is limited to 70-80 dB SPL over the high frequency range (Lopponen and Sorri (1991)) and the sensitivity of the ear decreases abruptly as a function of frequency, majority of the test subjects could not hear the electric bone-conduction signals at frequencies above 12kHz. The masking level had to be at least 50-60 dB SPL before the minimum masking level could be reached at 8kHz and above. The cross-hearing results showed that the Sony MDR-V4 earphones were almost comparable to the insert earphones in the high frequency range. These supra-aural earphones had a rather small contact area between skull and cushions. This probably

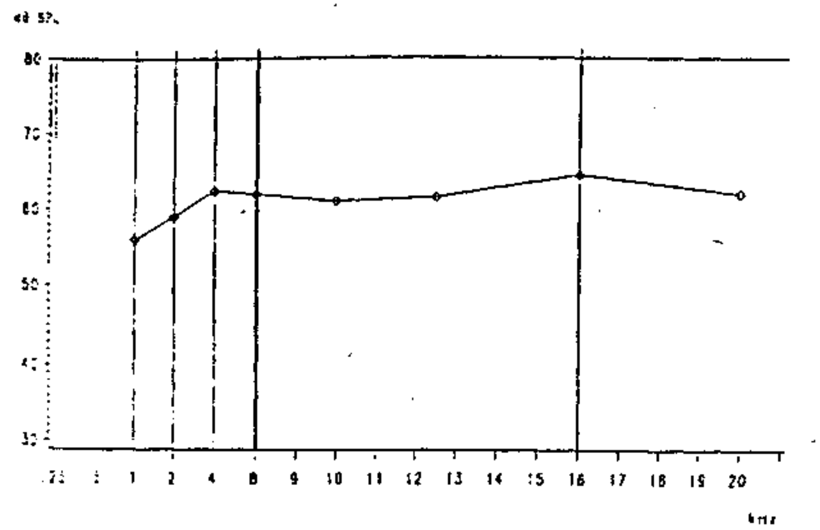


Fig III (1): Measured sound pressure levels of the Sony MDR-V4 earphones with white noise when linear noise level was 71 dB SPL. The abscissa is logarithmic in the conventional frequency range and linear from 8 to 20 kHz.

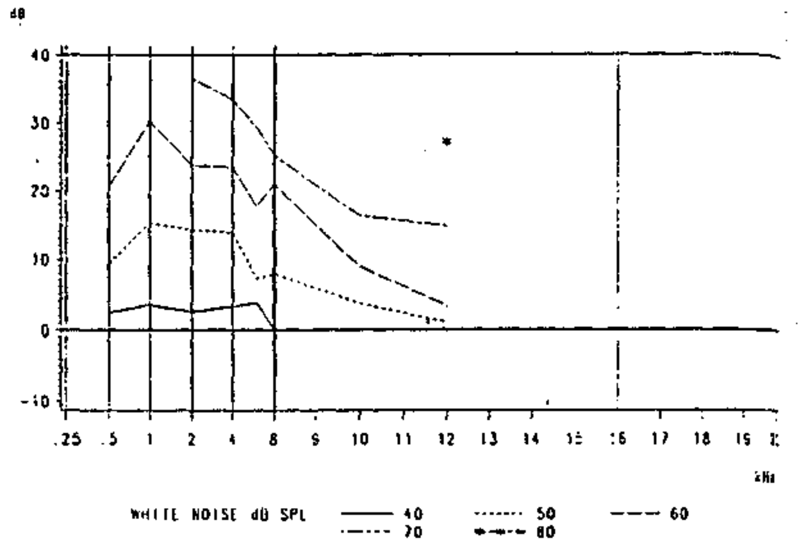


Fig III (2): The medians of the differences between the masked and unmasked electric bone-conduction thresholds of 8 ears of the unilaterally deaf subjects, when ipsilateral white noise masking level was varied between 40 and 80 dB SPL.

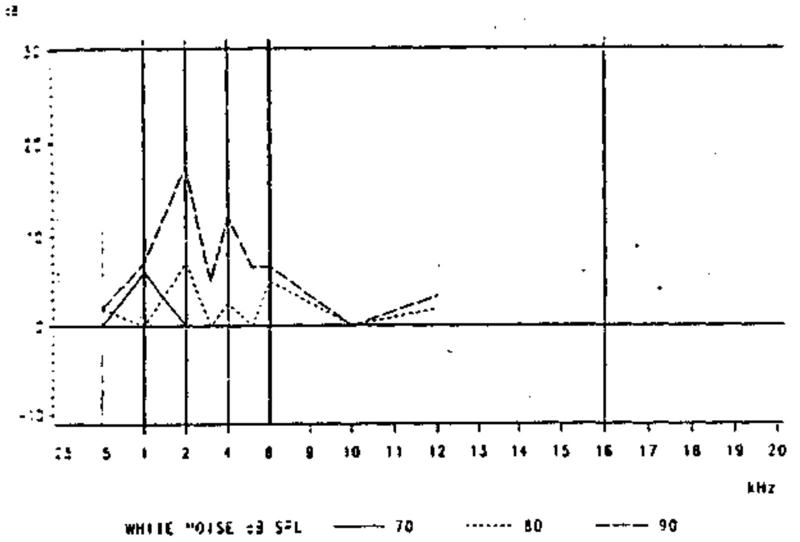


Fig III (3): The medians of the differences between the masked and unmasked electric bone-conduction thresholds of 8 ears of unilaterally deaf subjects, when contralateral white noise masking level varied between 70 and 90 dB SPL.

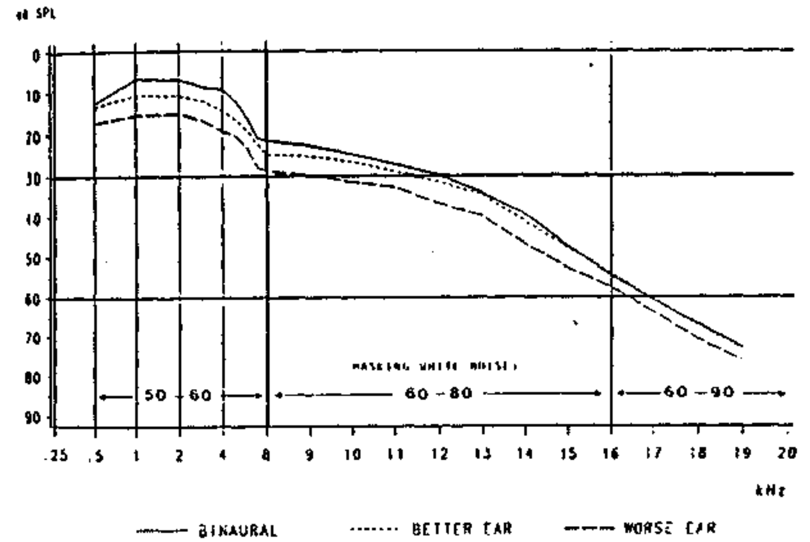


Fig III (4): The mean binaural, the better and the worse ear's electric bone-conduction thresholds (equivalent to dB SPL according to 40 log(i) re 1 mA and an additive frequency dependent correction) of 104 young subjects.

explained the good interaural-attenuation values measured. White noise was used for masking and it was used to ensure masking of both the fundamental signal and distortion products. It could also ensure that the masking signal was sufficiently broad-banded since critical band values have not been established at frequencies above 10kHz. The results through 14kHz agree closely with the earlier reports given by Dirks and Malmquist (1964) and Mc Dermott et al. (1990). The constant difference found in the better and worse ear's thresholds indicates that masking was effective even at high frequencies. Therefore it may be assumed that either binaural summation and or central masking diminishes at the highest frequencies or that this effect is due to direct electrical stimulation.

Hallmo, Sundby, and Mair, *I* (1992) investigated and compared both the interaural attenuation for air- conduction and bone-conduction signals and central and cross - masking in the conventional and high-frequency ranges and established a suitable clinical masking procedure for high-frequency. They took 24 unilaterally deaf subjects (13 males and 11 females) for experiment I, II and III. Seven of them had been operated on for a vestibular schwanomma. 10 of them had history of epidemic parotities. Seven had unknown etiology. 33 subjects (11 males and 22 females) aged 20-44 years took part in experiment IV and V. Madsen OB 70 through TDH 39 earphones and Interacoustics AS 10 HF through Koss HV/IA earphones were used for measuring conventional frequencies and high-frequencies respectively. Pracitronic KH70 bone vibrator were used for measuring bone-conduction thresholds. Narrow band noise was used to mask air- conduction and bone-conduction at conventional frequencies and 1/3-octave filtered white noise geometrically centered at the frequency of the test tone obtained from a Bruel and Kjaer Random noise generator 1402 and a Nortronic universal filter model IV at the high-frequencies.

The following studies were performed. They are:

1) Interaural air-conduction attenuation:-conventional frequency and high-frequency thresholds obtained for the deaf and hearing ear. Interaural attenuation is the difference between these two thresholds.
2) Interaural bone conduction attenuation,
3) Minimum masking level.-The minimum masking level is defined as the lowest masking level which just produced a change in puretone threshold.
4) Central masking:-The magnitude of central masking is obtained by subtracting the unmasked from the masked bone conduction threshold.
5) Cross masking level.

The results showed that the interaural attenuation for the TDH 39, varied from 43 dB at 0.125 kHz to 67dB at 4kHz, the mean across frequency attenuation being 58dB. For Koss HV/1A, the lowest attenuation obtained was 35dB at 2kHz and highest was 50dB at 0.125 kHz with a mean across frequency value of 43 dB. In high-frequency range, attenuation varied from 29dB at 18kHz to 38dB at 9, 10 and 14 kHz with mean across frequency of 35dB. Occlusion of the test ear canal increased attenuation with the Koss headset at all frequencies except 0.125 kHz. In the high-frequency, the increase in attenuation ranged from 14dB at 17kHz to 26dB at 9kHz. Interaural attenuation for the frequencies 8-17 kHz was on average lOdB, range 2 to 14 dB, lower with the inactive ipsilateral earphone sited supra -

vis-a-vis antero- auricularly. This difference was 3dB at 6kHz and sank to practically OdB at lower frequencies. (Fig. III(5)).

Interaural bone-conduction attenuation results showed mean values increased from 4 to 15 dB for the conventional frequency range of 0.25 to 6kHz and fell from 14 to 6dB for the high-frequency range of 8 to 16kHz. (Fig. III (6)). The maximum ranges in conventional frequencies is 35 dB at 6kHz and for high-frequency is 45dB at 11 kHz. (Table III (3)) The mean minimum masking level varied from 4-6 dB for frequencies 8-12 kHz and 9-15 dB for 13-16 kHz. (Table III(4)).

Table III(3). Interaural attenuation for BC signals; negative values are bracketed.

kHz	*X*	SD	Range	*N*
0.25	4	6	(-IO)-IO	
0.5	6	6	0-20	
1	5	5	(-5)-15	
2	10	7	0-25	
4	11	8	0-25	
6	15	8	0-35	
8	14	6	5-30	22
9	14	7	5-30	21
10	13	10	(-5)-30	21
11	14	10	(-5)-40	20
12	11	8	(-10)-30	19
13	8	8	(-10)-20	17
14	10	8	(-10)-20	13
15	8	9	(-15)-20	13
16	6	6	0-20	11

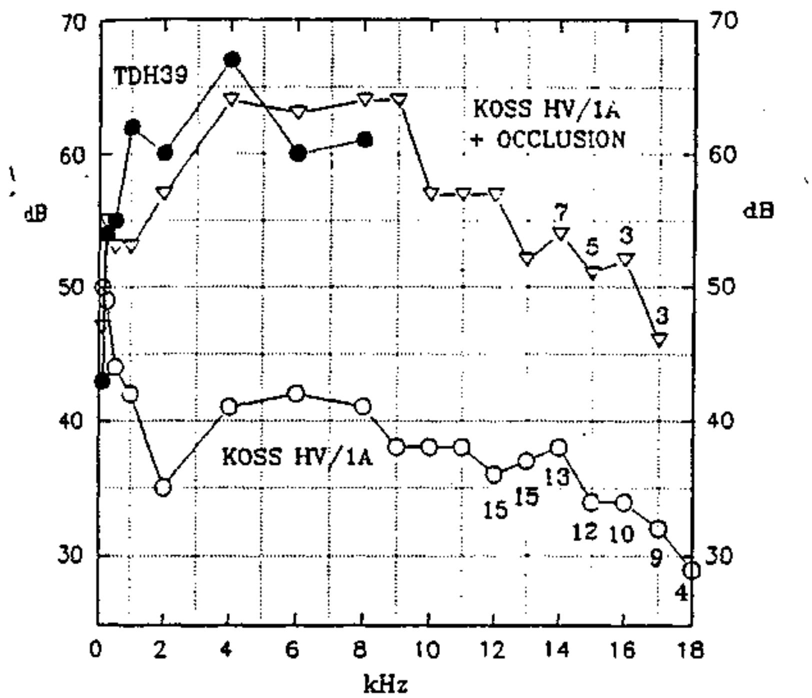
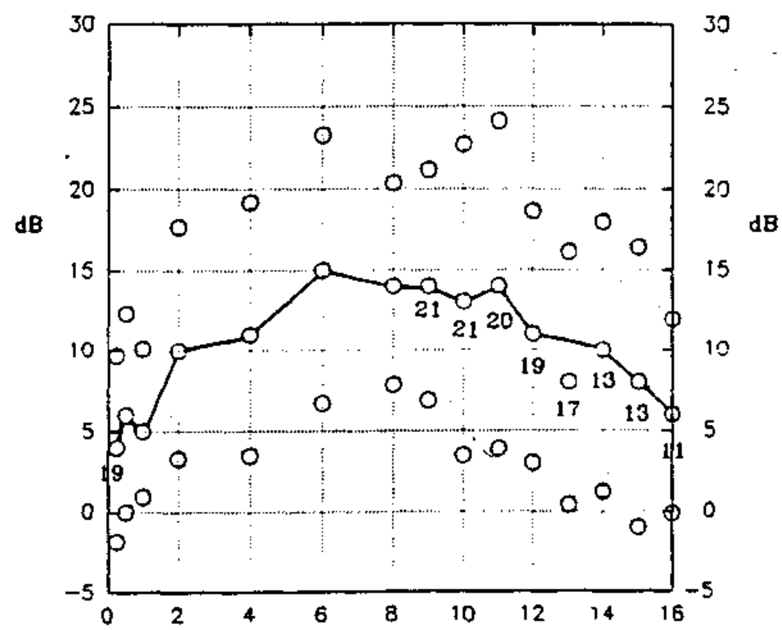


Fig III(5) : Interaural attenuation for AC signals of the TDH39 .-.) in the CF range and for the Koss HV/1A (O—O) in "oth the CF and HF ranges obtained in subjects with unilateral anacusis. The measurements with the Koss HV/1A were repeated with occlusion of the external ear canal on the htearing side (A—A). Numbers of subjects responding are deluded at 12-18 kHz.



FigIII(6): Interaural attenuation for BC signals, means and standard deviations, the Pracitronic KH70 being placed on the mastoid process of both the hearing and deaf ears in 22 unilaterally deaf subjects. The numbers of responding subjects at the highest frequencies are shown in the figure.

Table 1TT(4): Minimum masking level in the HF range masking noise being presented through the Koss HV/1A earphone placed supra-auricularly at the hearing ear in 13 unilaterally deaf subjects, the Pracitronic KH70 being sited centrally on the forehead.

	Minimum masking level		
kHz	*X*	SD	Range
8	5	3	0-10
9	4	4	0-15
10	4	4	0-10
11	5	5	0-15
12	6	6	0-20
13	10	5	5-20
14	9	6	0-20
15	10	5	5-20
16	15	7	0-25

The regression co-effecient of the early, low-slope masking curve [Table III(5)] varied from 0.11 at 4 and 6 kHz to 0.14 at 2kHz in the conventional-frequency range and in the high-frequency range from 0.08 at 12 kHz to 0.12 at 8,9 and 15kHz. With 30 dB effective contralateral masking, mean contralateral masking was 1.9 dB at 6kHz and varied from 1.6dB at 12kHz to 3.3 dB at 8 and 16 kHz in the high- frequencies. For the TDH 39, the cross masking level varied in the conventional-frequency range from 53 dB at 0.25 kHz to 63dB at 6kHz, the across conventional frequency mean being 57 dB. In the high-frequency range, the cross-masking level for the Koss HV/1A varied from 38dB at 16kHz to 48dB at 10kHz, with an across high-frequency mean of 44 dB. [Table III(6)]

Table III(5): Values for central masking in the CF (n=15) and HF (n=11) ranges in bilaterally hearing subjects expressed both as a regression coefficient (Regression) and at 30 dB effective masking level.

	Regression			30-3B masking		
KHZ	X	SD	Range	X	SD	Range
0.25	0.13	0.07	0-0.24			
0.5	0.13	0.09	0-0.30			
1	0.12	0.07	0-0.21			
2	0.14	0.07	0-0.27			
4	0.11	0.07	0-0.24			
6	0.11	0.07	0-0.27	1.9	2.4	0-5
8	0.12	0.06	0-0.25	3.3	2.4	0-5
9	0.12	0.08	0-0.22	2.1	2.5	0-5
10	0.11	0.14	0-0.48	2.9	2.5	0-5
11	0.09	0.06	0-0.17	3.2	3.0	0-10
12	0.08	0.07	0-0.20	1.6	2.2	0-5
13	0.10	0.10	0-0.33	2.1	2.5	0-5
14	0.09	0.06	0-0.16	2.3	2.5	0-5
15	0.12	0.06	0-0.22	3.0	5.0	0-15
16	0.09	0.09	0-0.28	3.3	3.2	0-10

Table III(6): Cross-masking data obtained in CF (n=15) and HF (n=13) in bilaterally hearing subjects with the TDH39 and the Koss HV/1A earphones respectively.

	Cross-masking		
kHz	*X*	SD	Range
0.25	53	8	50-70
0.5	55	6	50-75
1	56	8	55-80
2	55	8	50-80
4	61	9	55-80
6	63	8	50-80
g	45	8	29-54
9	44	8	30-55
10	48	8	35-65
11	45	8	33-58
12	45	7	35-55
13	42	8	30-55
14	45	11	31-66
15	47	10	34-65
16	38	10	21-51

The recommendations for high frequency masking procedure are:

1. Masking is introduced to the contralateral ear at 5-15 dBSL (i.e.) at the minimum masking level which varies with test frequency.
2. Hearing threshold for the test tone is determined at successive 5dB increments of the contralateral masking. If the former remains unchanged during at least a 15dB increase in masking level, the correct threshold for the tone has been found. If tone threshold is raised by 5dB for each 5dB increase in masking level, it is the contralateral, masked ear which is responding and the masking level must be further increased by 5dB steps until a tone threshold plateau is reached.
3. Since there is no occlusion effect in the high-frequency range (Hallmo et al. 1991), occlusion of the test ear is employed in bone-conduction threshold determinations to avoid possible acoustic stimulation by air-conduction and/or transmission through the headset.

CLINICAL IMPLICATIONS

The interest in testing high-frequencies is primarily connected with deviations in the human hearing acuity in high-frequencies. The information from early high-frequency audiometry can lead to preventing damaging frequencies within the conventional audiometry range. High-frequency (>8kHz) thresholds are not predictable from thresholds in the conventional frequency range (Erickson et al. (1980); Fausti et al., (1981)). The effects of noise exposure (Flottorp, 1973; Erickson et al., 1980; Fausti et al., 1981) or ototoxic agents (Dreschler et al., (198); Rappaport et al., (1986) tend to be evident, first, at high-frequencies and considerably later, at lower frequencies. Thus, high-frequency sensitivity can provide an early warning of cochlear damage and subsequent speech reception difficulties, at least for adults (Henry et al., 1985). Studies have shown the selective or early involvement of high-frequency hearing in certain auditory and extra-auditory pathologies: Rosen and Olin (1965) in peripheral vascular disease; Cunnigham and Goetzinger (1974) in patients with hyperlipemia. Jacobson et al. (1969) studied that patients treated with ototoxic drugs found a considerable high-frequency hearing loss 41-76 days prior to involvement of hearing in speech frequency range. Many authors have studied the relationship between high-frequency thresholds and industrial noise, (Sataloff et al. (1967), Robertson and Williams (1975), Osterhammel (1979), Dieroff (1982), Luts (1982), Filipo and DeSeta (1983).

Many authors have studied hearing loss in diabetes mellitus [Osterhammel and Christau (1980)]. Filipo et al. (1985) had carried out studies on the high-frequency function in subjects suffering from juvenile diabetes. They came to the conclusion that there is no early involvement of the ultra-audiometric frequencies in this disorder. Cunningham et al. (1983) found a relatively lower threshold for high frequencies in smokers, though this was not statistically significant. High-frequency hearing loss has also been correlated with otosclerosis, hereditary sensorineural hearing loss and Meniere's disease (Osterhammel, 1980).

The following chapter deals with various studies about the clinical applications of high frequency audiometry done during the years 1988 to 1998.

Otitis Media:

Secretory otitis media is characterized by the presence of non-supperative effusion in the middle ear cleft and is the most common cause of hearing loss in children. It usually affects both ears. Adenoidectomy, myringotomy with aspiration of middle ear fluid and transmyringeal insertion of ventilation tubes are widely used surgical treatments. A number of studies have suggested that sensorineural hearing loss may be a sequelae of otitis media (OM). Clinical studies have demonstrated elevated bone conduction thresholds in patients with chronic or recurrent otitis media (Hulka, (1941); Dommerby, and Tos, (1986), Levine, Shelton, Berliner, Sheehy, (1989), Paparella, Brady, Hoel, (1970), Cusimano, Cocita, D'Amico, (1989), Arnold, Ganzer, Kleinmann, (1977). Because frequency coding along the basilar membrane progresses from high to low frequencies with

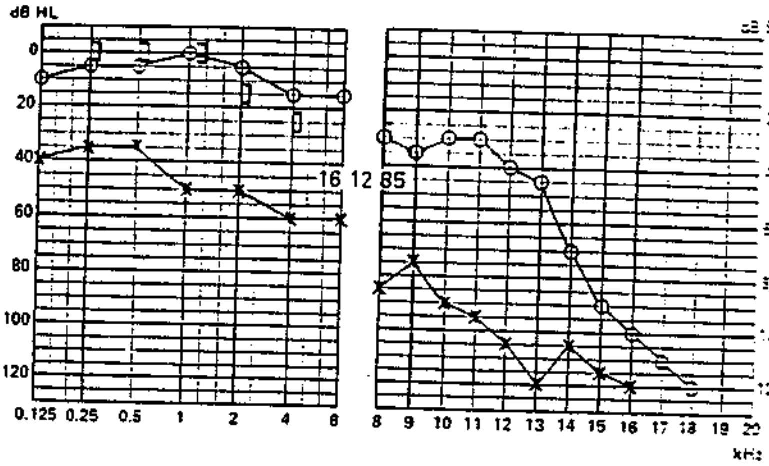


Fig IV (1) Preintubation conventional (dB hearing level) and extra-high frequency (dB sound pressure level) thresholds in patient with unilateral secretory otitis media. Note linear frequency scale above 8 kHz.

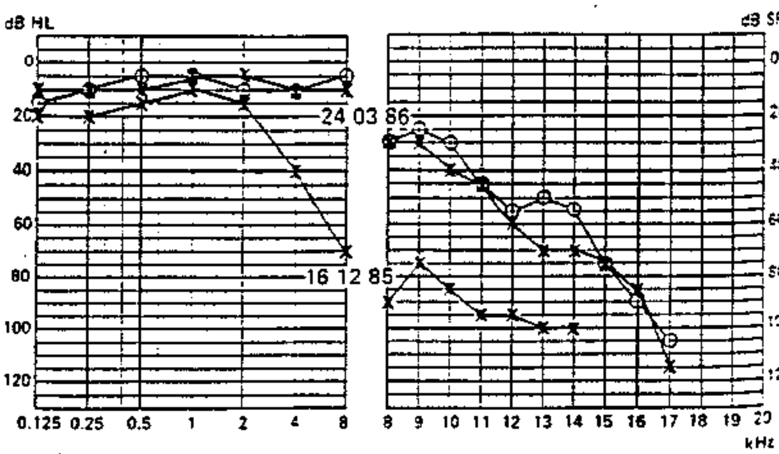


Fig IV (2) Air conduction thresholds immediately after intubation of left ear (Dec 16, 1985) and 3 months later (March 24, 1986). Threshold normalization occurred up to and including 2 kHz on day of operation, while threshold is virtually unchanged in 8- to 14-kHz range. High frequency and extra-high frequency thresholds are, however, symmetric 3 months later.

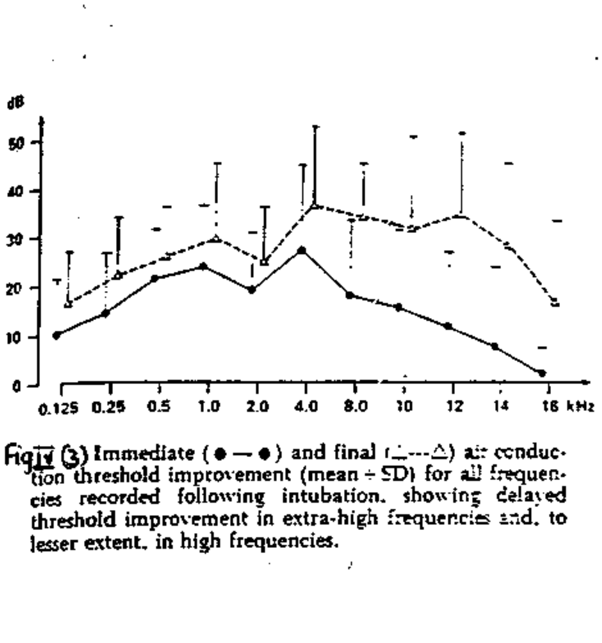


Fig IV (3) Immediate (● — ●) and final (△---△) air conduction threshold improvement (mean + SD) for all frequencies recorded following intubation, showing delayed threshold improvement in extra-high frequencies and, to lesser extent, in high frequencies.

distance from the basal end of the cochlea, sensorineural hearing loss produced by diffusion of otitis media related toxins across the round window membrane would be expected to preferentially affect high frequency hearing. Studies have demonstrated a relationship between otitis media and hearing loss in the extended high frequency range (8 to 20 kHz). (Mair, Shoel, Elverland, (1989), McDermott, Fausti, Frey, (1986).

Mair, Fjermedal, Laukli, (1989) had made a comparison of air conduction threshold changes upto one year after myringotomy, aspiration of middle ear fluid, and insertion of ventilation tubes in ten patients with bilateral secretory otitis media and twelve patients with unilateral secretory otitis media. Conventional air and bone conduction audiometry and air conduction thresholds in the extended high frequency range of 8 to 20 kHz was performed the day before or the actual day of operation. [Fig. IV (1)]

These testings were repeated immediately after or within 24 hours of tube placement and subsequently at different intervals upto one year post operatively. The instruments employed for the conventional and extended high frequency audiometry were the Madsen OB 822 and the Demlar 20K audiometers respectively The pure tone thresholds have been analysed in three frequency groups:

- low frequency (0.25, 0.5, 1kHz),
- high frequency (2, 4 and 8kHz) and
- extended high frequency (10, 12,14 and 16 kHz).

The results showed that in low frequency and high frequency ranges, significant improvement came during the first 24 hours after intubation, while in the extended high-frequency range, threshold lowering occurred gradually over the following two months. (Fig. IV (2) and Fig. IV (3)). The results were statistically significant.

The various explanations given by the authors for these findings are that ventilation of the mesotympanum may reduce the stiffness of the middle ear transformer sufficiently to allow threshold normalization at the conventional audiometric frequencies, whereas lesser amounts of retained mucus or mucosal edema in the epitympanum or in the window niches may either increase the mass of the system, and thus delay threshold improvement in the extended high-frequency range, or influence the incudomallear rotation axis, which is known to be frequency dependent (Gyo, Aritomo , Goode, 1987). Subsequent resorption of epitympanal mucus, or its removal by mucociliary transport, could then be reflected in a gradual lowering of extended high-frequency threshold, as demonstrated in this study. Residual epitympanic or circumossicular disease could result in a permanent increase in the mass of the system and thus persistently high extended high-frequency threshold which was observed in four out of six patients with unilateral secretory otitis media in this study.

Additional factors are the presence of a defect in the tympanic membrane after intubation and the presence of the ventilation tube, which has an appreciable length relative to the thickness of the drumhead. The effect of the grommet will be variable, since resistance of a canal is related directly to length. The vibration pattern of the tympanic membrane become exceedingly complex at higher frequencies (Konradsson, Ivarsson, Bank, 1987) and decoupling of the membrane from the mallear handle occurs at frequencies above 3 to 4 kHz in both cats and humans (Khanna, Tonndorf, (1972), Tonndorf, Khanna, (1972). Indeed, it could be argued that the ossicular chain does not contribute appreciably to transfer of extended high frequency acoustic energy to the inner ear. This possibility could also explain the high thresholds at these frequencies and that stapes foot plate movements are a result of direct acoustic stimulation from the tympanic membrane. The pathologic epitympanic changes postulated above could, however, influence stapes movements as a result of changes in reactance.

Margolis, Hunter, Rykken, Giebink, (1993) studied extended high frequency hearing in children with and without histories of chronic or recurrent otitis media. This investigation was undertaken to:

1. Obtain normative data for extended high frequency hearing thresholds in 3 to 10 year old children.
2. Evaluate test-retest reliability of extended high frequency hearing threshold in normal children.
3. Study the effect of otitis media on extended high frequency hearing in children with various residual middle ear conditions, evaluated by multi-frequency tympanometry.

Twenty one children (41 ears) in each one year age interval from 3 to 7 years with normal hearing were taken. In the otitis media group 49 ears were tested of age group 3-7 years. The conventional and extended high frequency audiometry was performed with a clinical audiometer (Virtual mode 320). The transducers used for conventional air conduction and bone conduction and extended high-frequency were Telephonics TDH-50P, Radio ear B-71 and Koss Pro/4XPlus respectively. Multifrequency tympanometry was performed with a computer controlled acoustic immitance system (Virtual model 310) that provided probe frequencies ranging from 226 to 2000Hz.

The results of this study are as follows:

- **Test-retest reliability:** The test-retest difference for all test frequencies combined was 3.8 dB and the reliability co-efficient was 0.98 [Fig. IV(4)]. The extended high-frequency threshold were found to have good test-retest repeatability.
- **Normal extended high-frequency thresholds:** The extended high-frequency thresholds tend to improve with age. But it was not statistically significant at the 0.5 confidence level (P=0.09) (Fig. IV (5), Fig. IV (6)).
- **Extended high-frequency hearing in children with otitis media:** Fig. IV (7) presents extended high-frequency hearing thresholds for the normal children and for children with histories of chronic or recurrent otitis media. The otitis media group were separated by tympanometric results in order to explore the possible effects of residual middle ear disease. Tympanometric results were classified as normal or abnormal based on 226-Hz admittance magnitude tympanaograms and multifrequency tympanograms. The criteria for grouping subjects according to tympanograms are present in the Table IV(1). (Margolis, Heller, (1987) and Vanhuyse, , Creten, Van Camp, .(1975).)

An analysis of variance indicated that the differences among groups were significant (P = 0.0001). Post-hoc analysis revealed that the normal

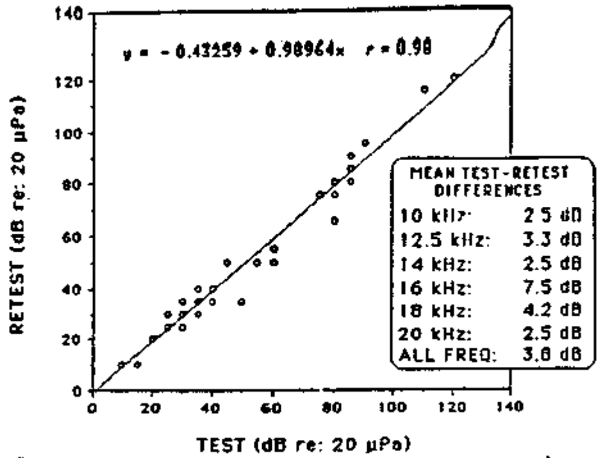


Fig IV (4): Test-retest scatterplot of extended high-frequency thresholds from six ears of three children. Values in inset are mean absolute values of test-retest differences.

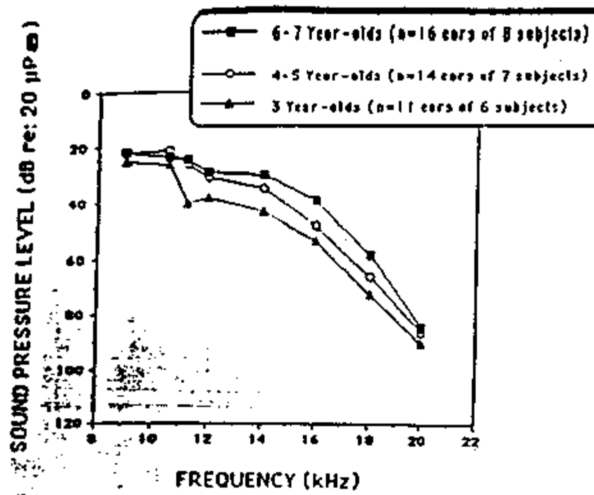


Fig IV (5): Mean extended high-frequency thresholds for 3- to 7-year-old children divided into three age groups. There was systematic effect of age, with auditory thresholds decreasing with age.

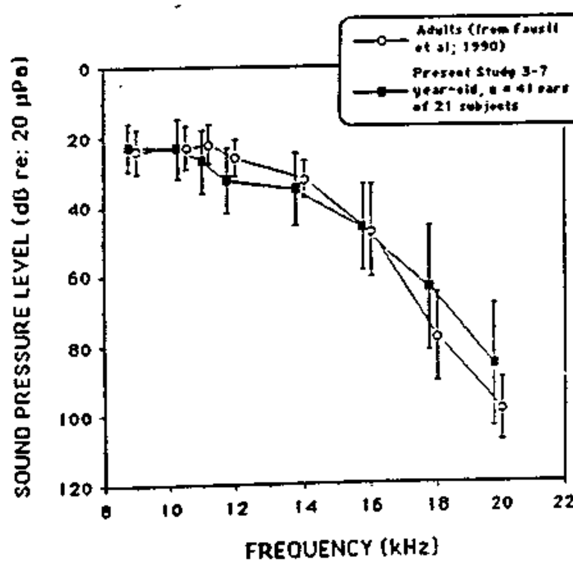


Fig IV (6) Mean extended high-frequency thresholds (±1 SD) for 3- to 7-year-old children and for young adults (ages 18 to 25 years). Adult data are from Fausti et al.[20]

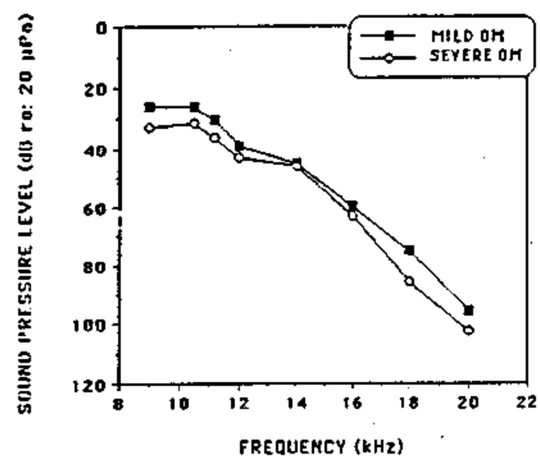
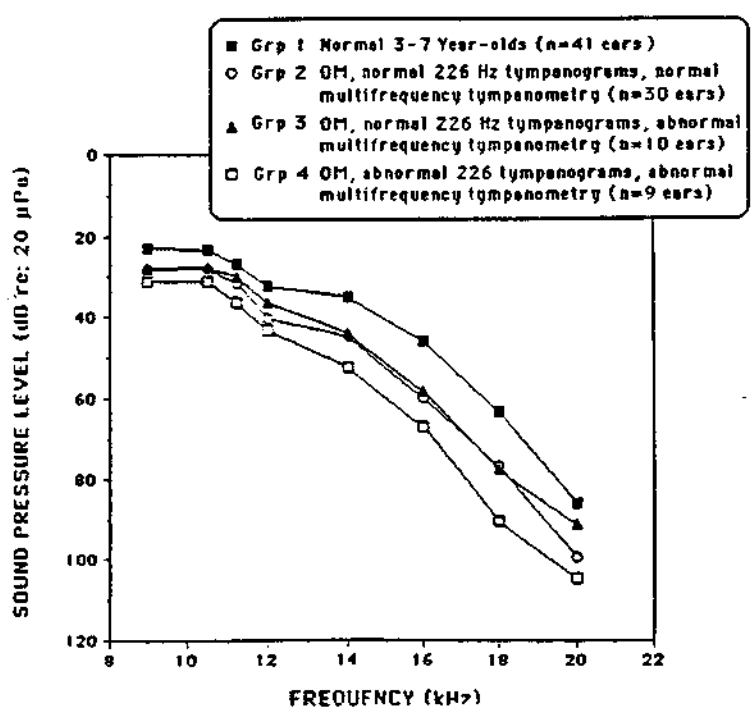


Fig IV (8) Mean extended high-frequency thresholds for otitis media (OM) subjects classified according to severity.

Fig IV (7) Mean extended high-frequency thresholds for normal 3- to 7-year-old group (group 1) and for three groups of children with histories of chronic or recurrent otitis media (OM). Otitis media subjects are divided into three groups based on tympanometry as follows: normal 226-Hz and multifrequency tympanograms (group 2); normal 226-Hz tympanograms and abnormal multifrequency tympanograms (group 3); abnormal 226-Hz and multifrequency tympanograms (group 4). Otitis media children had normal hearing in conventional-frequency range, no air-bone gaps, and no otoscopic evidence of active OM at time extended high-frequency threshold measurements were made.



group was significantly different from all other groups (P=0.002, 0.03, and 0.0001 for groups 2, 3 and 4 respectively). A comparison of groups 2 and 3 pooled against group 4 yielded a significance level of 0.09, suggesting a trend for those with abnormal 226-Hz tympanograms to have poorer hearing than subjects with normal 226-Hz tympanograms.

Table IV (1): Criteria For Otits Media Groups By Tympanometry Results

	226-Hz Tympanogram	Multifrequency Tympanograms
Normal control group		
Group 1	Normal	Normal
History of otitis media		
Group 2	Normal	Normal
Group 3	Normal	Abnormal
Group 4	Abnormal	Abnormal

All groups with history of otitis media had no otoscopic evidence of it at the time of testing, had normal hearing in range 250 to 8.000 Hz (< 15 dB hearing level), and had no air bone gap exceeding (5 db) 5 db in range 250 to 4000 Hz.

* Normal if static admittance (compensated by using negative tail) was 0.22 to 0.81 milimoles and if tymphonometric width (gradient compensated at + decapascals. was 59 to 151 decapascals, Ranges are from previously published normative study.

** Normal if shapes followed model of Vanhuyse et al and if resonance (susceptance notch = positive tail) occurreed in range 800 to 1600 Hz.

In order to explore the effect of otitis media severity on high-frequency hearing, the otitis media subjects with normal 226-Hz tympanograms were classified as having mild or severe otitis media on the basis of frequency of otitis media at the time of their quarterly study visits. Children who had otitis media at 25% or fewer of study visits were classified as having mild otitis media. Those with otitis media at more than 25% of study visits were classified as having severe otitis media.

Fig. IV (8) suggests that there is a trend for children with more severe otitis media to have poorer high-frequency hearing. The difference did not reach statistical significance at the 0.05 level (P=0.07).

The authors in the study had taken several steps in this investigation to control for residual middle ear disease. First, subjects were eliminated if they had otoscopic evidence of active otitis media. Second, otitis media subjects were selected who had no air-bone gaps in the conventional frequency region. Third, otitis media subjects were separated by tymponometry in an attempt to evaluate the likelihood of residual middle ear disease. Subjects with normal 226 Hz tympanograms and normal multifrequency tympanometry have the least likelihood of residual mechanical disturbances of the middle ear. These subjects had poorer hearing than their normal counterparts at all frequencies tested. Those with normal 226Hz tympanograms and abnormal multifrequency tympanometry did not differ from those with normal multifrequency results. These abnormalities in the multifrequency tympanograms were predominantly characterized by high admittance and low resonant frequency, probably because of monomeric tympanic membranes. Monomeric tympanic membranes are not likely to affect high-frequency hearing, because the region of the eardrum that is likely to be scarred contributes little to ossicular chain vibration at high-frequencies (Tonndorf and Khanna, 1972). The group with abnormal 226-Hz tympanograms tended to have the poorest high-frequency hearing, perhaps reflecting a residual middle ear component as well as an inner ear component.

Therefore, the study reveals that the extended high frequency thresholds were found to have good test-retest repeatability. Children with otitis media histories had poorer extended high-frequency hearing than children without otitis media histories. The extended high-frequency hearing in otitis media children appeared to be related to otitis media severity. Children with residual tympanometric abnormalities had poorer extended high-frequency hearing than otitis media children with normal middle ear function. Also the results showed evidence for middle ear and inner ear components of extended high-frequency hearing losses in children with otitis media.

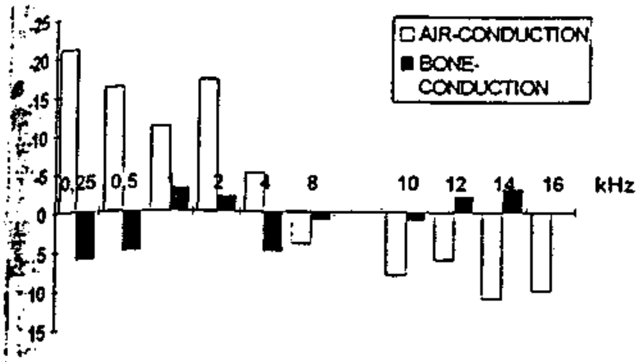
Mair, and Hallmo, . (1994) compared the pre-and post-operative air-and bone-conduction thresholds in the conventional and extended high-frequency ranges in 22 subjects (14 male and 8 females) with an age range of 8 to 38 years (median 20 years) in whom successful myringoplasty was performed. Air-conduction pure-tones were generated by Madsen OB70 and Interacoustics AS10HF audiometers in the conventional and extended high-frequency (9-18 kHz) ranges respectively and the ear-phones used were TDH 39 and Koss HV/1A in the conventional and extended high-frequencies respectively. Bone - conduction thresholds were measured using the Pracitronic KH70 bone vibrator in both the frequency levels (upto 16kHz). Masking noise for cxir-conduction and bone-conduction was narrow-band noise for the conventional frequencies and 1/3 octave filtered white noise geometrically centered at the frequency of the test tone for the extended high-frequency range.

The results showed that the air-conduction thresholds improved through 4 kHz, but were elevated post-operatively for the frequencies 6 through 18 kHz. Post-operative bone- conduction thresholds were elevated at 025 and 0.5 kHz, were lower by 2-8 dB for 1, through 3 kHz and not significantly altered in the extended high-frequency range of 8 through 16 kHz. (Table IV (2), (3) Fig. IV (9)).

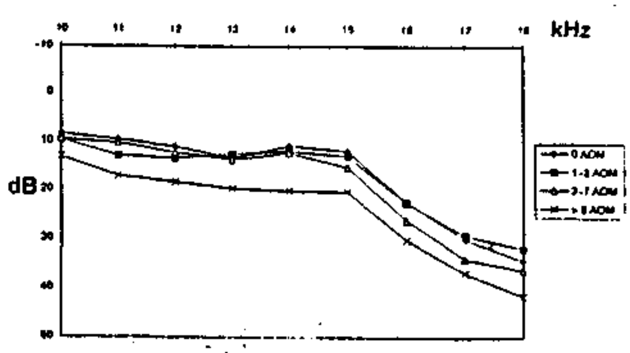
Table IV (2) Changes in AC thresholds following success myringoplasty, mean standard deviation (SD) and range negative values represented lower postoperatire thresholds. The two values at 8 kHz are obtaind with the Madsen OB70 and the Interacoustics AS10HF respectively.

kHz	Mean	SD	Range	
0.125	-23	12	-45	0
0.25	-21	14	-45	**5**
0.5	-16	11	-40	**5**
1	-11	10	-35	10
2	-17	11	-40	0
3	-12	9	-30	0
4	-5	12	-30	25
6	5	13	-30	35
8	4	15	-30	35
g	2	14	-30	35
9	3	18	-40	50
10	8	17	-30	55
11	5	18	-35	**55**
12	6	16	-25	**55**
13	7	14	-25	35
14	11	13	-15	**35**
15	11	12	-10	35
16	10	10	-10	35
17	7	9	-10	20
18	9	8	-5	20

The study indicated that the air-conduction threshold elevation in the extended high-frequency range is a consequence of impaired transmission and does not indicate intra-operative damage to the base of the cochlea.



FigII(9)Mean differences in dB between the pre- and postoperative AC and BC thresholds in the frequency range 115-16 kHz. Negative values represent lower postoperative thresholds.



FigIV(10):The mean pure tone high frequency hearing thresholds in the right ears of children with dill'crent histories of AOM. The number of children: 0 AOM: 97: 1-2 AOM: 118: 3-7 *AOM:* 153: and ≥8 AOM: 205.

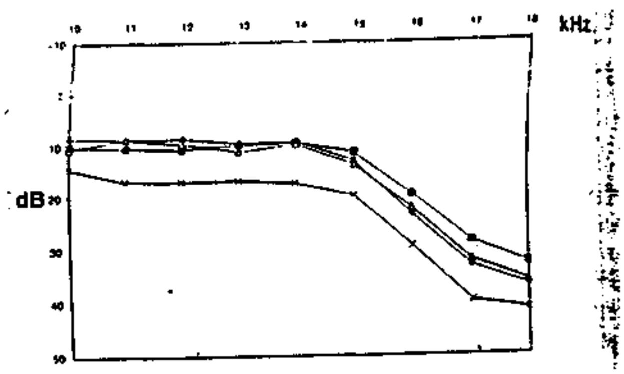


Fig IV (11) : The mean Pure tone high hearing thresholds in the left cars ol" children with dillcrcnl historics of AOM. TI!C number or children was: 0 AOM: 97; 1-2 AOM: 118; 3-7 AOM: 153; and z8 AOM: 205.

Investigations using the homodyne interferometer have confirmed that the feline tympanic membrane vibrates in phase upto 1kHz. and out of phase at higher frequencies upto 20kHz, the tympanic membrane resonances at these frequencies being, however, largely averaged out in the response of the malleus handle. (Decraemer et al., 1989). In addition, it has been shown that the mode of vibration of the malleus at high frequencies is not around the

Table IV (3): Changes in AC thresholds following success myr Myringoplasty. mean standard deviation (SD) and range negative values represented lower postoperatire thresholds. The two values at 8 kHz are obtaind with the Madsen OB70 and the Interacoustics AS10HF respectively.

kHz	Mean	SD	Range
0.25	-6	8	-10 15
0.5	-5	10	-15 15
1	-3	9	-15 10
2	-2	7	-15 5
3	-8	8	-15 0
4	-5	8	-5 15
8	1	8	-10 30
9	1	7	-10 25
10	1	9	-10 35
11	0	8	-10 25
12	2	9	-15 30
13	3	8	-15 20
14	3	6	-15 5
15	2	8	-15 15
16	0	7	-10 15

classical incudomallear rotation axis but can be translational, rotational, with different axes which may even be inferior to the umbo, or a mixture of both modes. (Decraemer et al., 1989, 1991). Frequency dependent changes in the rotation axis have been described by Gundersen and Homoen, (1976). Middle ear transmission function is, therefore, very complex in the extended high-frequency range. The shape, thickness and anisotropy of the tympanic membrane have been shown to be important factors for sound transmission in the middle ear (Funnell and Laszlo,(1982); Williams and Lesser, (1990)). It is, therefore, perhaps not surprising that replacement of the structurally highly organised lamina propria of the pars tensa of the tympanic membrane (Lim, 1970) by the histologically different temporalis fascia used in myringoplasty will result in poorer transmission in the extended high-frequency range where mechanical coupling is more complex. The defective transmission in the extended high-frequency range found in this study could also be ascribed to minor changes in the ossicular chain secondary to previous otitis media or ear trauma, or to a combination of these factors.

Laitila, , Karma, Sipila, Manninen, .. and Rakho, (1997) studied the extended high-frequency hearing of 573 white, urban, mean 13.8 year old unselected children in Tampere, Finland. (285 boys and 288 girls were examined at ages varying from 12 years 11 months to 14 years 8 months). All their ear-related morbidity had been recorded since their birth and they had been examined at the ages of seven months, two years and some of them at five years. The extended high- frequency audiometry was measured from 10 to 18 kHz, with 1 kHz steps and the results were related to the number of attacks of acute otitis media they had experienced. The mean puretone hearing thresholds varied from 10.7 dB at 10 kHz to 37.0 dB at 18kHz in the right ears (Fig. IV (10)) and between 11.6 dB at 10 kHz and 37.4 dB at 18 kHz in the left ears (Fig. IV (11)).

Among those with greater or equal to eight attacks of acute otitis media the thresholds were highest, the difference between them and each of the first three groups being statistically significant at 13 and 14 kHz. From 11 to 16 kHz the same difference was significant between the last (greater or equal eight acute otitis media) and at least two of the first three acute otitis media groups. Numerous attacks of acute otitis media will have a harmful effect on high-frequency hearing in the long term was the conclusion of this study.

Lopponen, Sorri, Pekkala, and Penna, (1992) followed up 31 children (mean age 13 years; range 8.5 - 17.2 years) who had been treated with tympanostomy for secretory otitis media during the years 1977-1980. 29 normal age peers were taken as controls. The test battery included pneumatoscopical examination, conventional pure-tone audiometry and high-frequency air-conduction and electric bone-conduction audiometry. High-frequency hearing losses (6-18 kHz) were found as sequelae of secretory otitis media. The median threshold differences between the secretory otitis media group and the controls varied from 0 to 10 dB depending on the frequency. The hearing losses were considered to be of the conductive type, and probably related to changes in the tympanic membrane and the middle ear caused by secretory otitis media. On the other hand, it was also found that there was sensorineural hearing loss suggesting lesion at the cochlea.

Ototoxicity:

From a clinical point of view, ototoxicity is not a life threatening complication; but it should not be under- estimated. Usually some of the following factors were indicated to influence the onset of ototoxic damage: cumulative dose, individual dose, age, kidney functions, pre- existent hearing loss, and the simultaneous administration of more than one ototoxic drug. The various studies are lacking in uniformity, especially with regard to dose schedules. Experimental studies in which cisplatin was administered to guinea pigs and monkeys showed a remarkable dose-dependent loss of hair cells over the complete length of the basilar membrane, with a preference for the basilar turn of the cochlea, (Tange, 1984). Only Jacoboson et al., (1969); Fausti et al. (1984, 1976) mentioned clinically applied high frequency audiometry with patients treated with cisplatin or other ototoxic drugs. They described the early effects of ototoxic damage, especially in the perception of high- frequencies. High frequency loss was detected some time before the patient complained about tinnitus or vertigo, or before damage could be demonstrated in the conventional pure tone audiogram. As a screening of ototoxicity of platinum derivatives (CDDP) (Piel, Meyer, Perlia, et al., (1974); Helson, Okonkwo, Anton, et al. (1978); Aguilar - Markulis, Beckley, Priore, et al., (1981); Tange, Conijn, Van Zeyl, (1982); Van Zeyl, Conijn, Rodenburg, et al., (1984). High frequency audiometry contributes significantly to the early detection of ototoxic damage. (Jacobson, Downs, Fletcher, (1969); Fausti, Schechter, Rappaport, et al. (1984), Tange, Dreschler, Vonder Hulst, (1985). Cisplatin is effective as treatment for variety of carcinomas. Cisplatin also causes significant and permanent hearing loss in many individuals. [Waters, Ahmad, Katsarkas, Stanimir, McKay, (1991); Rossof, Stayton, Perlia, (1972); Fausti, Schechter, Rappaport, Frey, Mass, (1984)]. High dose cisplatin has been shown to

5

cause profound deafness [Buhrer, Weinel, Sauter, Reiter, Riehm, (1990)] Making rational decisions regarding modification of treatment with cisplatin requires quantitative observations of ototoxic effects that occur during treatment. The acquisition of such data can only be accomplished through systematic monitoring of hearing during the course of treatment. An effective hearing monitoring protocol should provide the earliest possible detection of hearing loss. Early detection does not in itself prevent further ototoxic damage. It will however, quantify ototoxic effects allowing modification of chemotherapy for an individual based on a total treatment protocol. Alteration of treatment could prevent further hearing loss. Hearing loss as a result of cisplatin treatment has been shown to typically begin in the highest frequency region corresponding with the basal end of the cochlea in animals (Barron, Diagneault, (1987)] and in humans [Pollera, Marollo, Nardi, Ameglio, Cozzol, Bevere, (1988)]. Investigators have evaluated hearing above 8 kHz and have found that it is these higher frequency thresholds that are usually affected, first, with hearing loss progressing to the lower frequencies throughout the course of cisplatin treatment [Kopelman, Budnick, Sessions, Kramer, Wong, (1988); Fausti, Schechter, Rappaport, Frey, Mass, (1984); Dreschler, van der Hulst, Tange, Urbanus, (1989)]. Once hearing loss is detected within the conventional frequency range, damage has already invaded the frequency range that can affect communication ability. The true incidence of ototoxicity due to cisplatin treatment is unknown, but reported incidence rates ranging from 3% [Forastier, Gennis, Orringer, Agha, (1987)] to 100% [Kopelman, Budnick Sessions, Kramer, Wong, (1988)]. Treatment with aminoglycosides is known to cause reversible hearing loss typically affecting higher - frequency hearing first and progressing to lower frequencies.

Dreschler, van der Hulst, Urbanus, (1988) had done high-frequency audiometry for patients treated with platinum and its derivatives using the technique introduced by Fausti et al. (1979). The study reported the results of periodic high frequency audiometry prior to each successive cycle of treatment. Seventy five patients divided into three groups according to different types of antineoplastic drug treatment (32 males and- 43 females) were taken Age range: -20 of them were between 0 and 30 yrs of age, 13 patients were between 30 and 45, 21 between 45 and 60 and 1 was over 60 years.

Group A-> 51 patients were treated with cisplatin 20 mg/m^2 , administered daily by a four-hour infusion for five consecutive days.

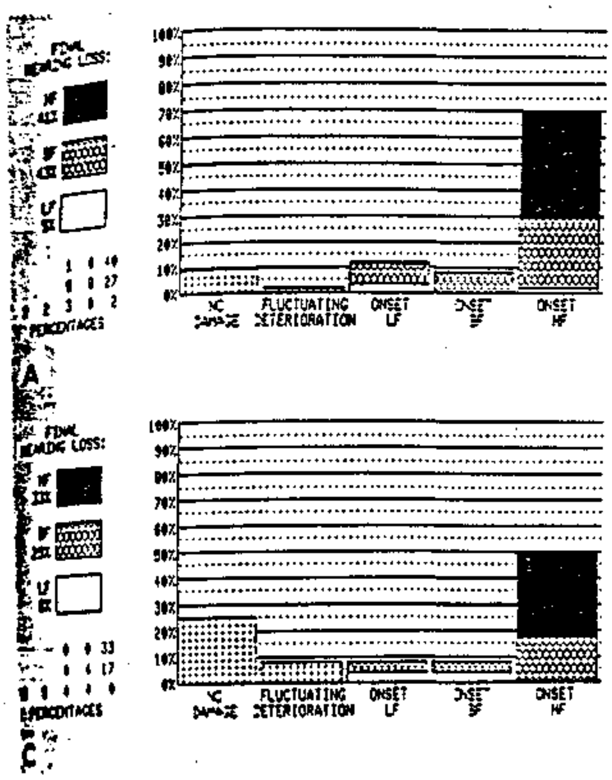
Group B -> 12 patients with cisplatin 50 mg/m administered once every four weeks by a four hour infusion.

Group C -> 12 patients treated with carboplatin 350 mg/m^2 given by a half hour infusion once every five weeks.

The instruments used were Interacoustics AC4 audiometer with TDH-39 headphones and Demlar HF audiometer with dynamic earphones with a ceramic diaphragm (Koss HV/IA) to measure pure-tone thresholds in the conventioned frequency (250 Hz to 8000 Hz) and high-frequency (8000 Hz to 20 kHz) ranges respectively.

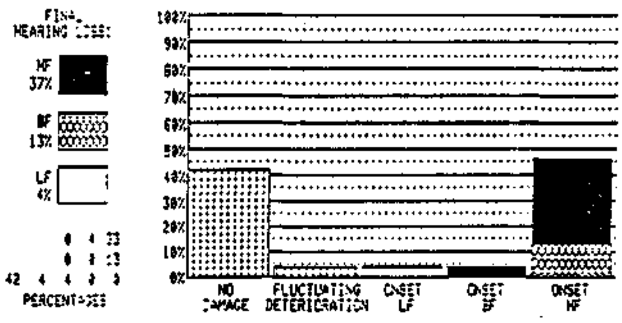
Fig. IV (12) shows the results of the three groups. The study showed a significant difference in patterns of ototoxicity between treatment with all the three groups. In all the three groups, ototoxic damage started mainly in the high-frequency range and was restricted to this range in 33% to 41%. It later developed into a broader - range hearing loss. In none of the three groups did the broader range frequency and low frequency hearing losses exceeded 12% of all the ears. Significant differences in the pattern of hearing loss were registered for the different platinum treatment groups in the study. In the groups who received cisplatin 50mg $/m^2$ and carboplatin 350mg$/m^2$, 42% and 25%, respectively, of the investigated ears proved to be undamaged, versus 9% undamaged in the group receiving cisplatin 20mg/m (P<0.01). Ototoxic hearing loss started mainly (46% to *10%)* in the higher frequencies (10000 to 18000 Hz) and developed into a broader - range hearing loss (1000 to 18000 Hz) during treatment in 13% to 43% (P<0.01). The onset of hearing damage was influenced by the patient's age (P<0.001) and the existence of a troubled ototogic history (P<0.05). In patients upto 30 years of age only 3% showed no damage after cisplatin 20 mg$/m^2$ treatment, whereas 90% developed high frequency onset damage. (Fig. IV (13)). .

In patients from 30 to 45 years of age, the same differentiation between no damage and high-frequency onset damage was recognised, but broad frequency final hearing deterioration was present in 60% of all ears. In oldest patient groups, the onset hearing loss was more localised in the low frequency



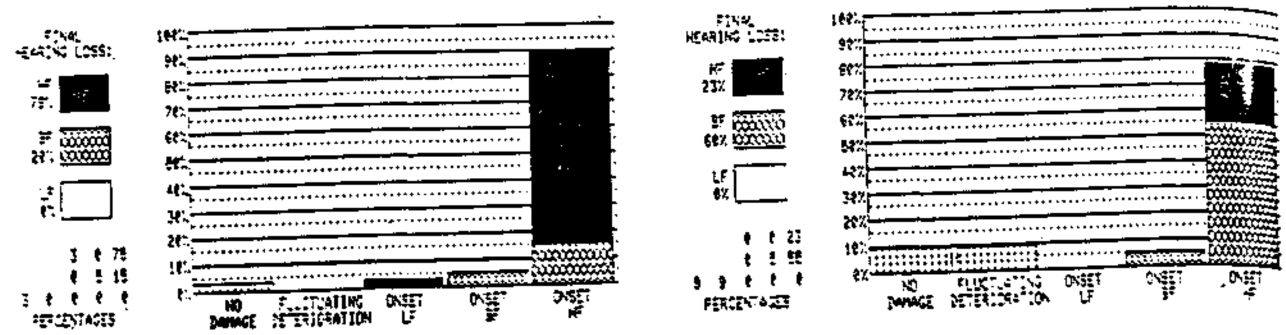
A

C



B

FigIV(12)Percentages of ototoxically changed ears (vertical axis) and patterns of ototoxicity (horizontal axis: see text). Fluctuating deterioration is deterioration not reproducible in final audiogram. Beside diagrim, percentages refer to different pattern blocs, which are divided vertically according to pattern of ototoxicity found in final audiogram. LF— low frequency, BF — both low and hieh frequency, HF — high frequency. A) Group A, cisplatin 20 mg·m^{1}. Pattern of ototoricity in 102 ears. E) Group B. cisplatin 50 mg'm^{2}. Pattern of ototoxicity in 24 ears. C) Group C, carboplatin 350 mg L1^{1} Pattern of ototoxicity in 24 ears.



A B

Fig IV (13):Group A. Patterns of ototoxicity in A) 40 ears of patients 0 to 30 years of age and B) 22 ears of patients 30 to 45 years of age.

and broad frequency ranges; in the final stage, there was no important difference between these oldest groups and the group 30 to 45 years age, because together the low frequency and broad frequency final hearing deterioration amounted to about 70% all ears. Obviously, with increasing age, the ototoxicity pattern shift to the low frequency range, in the onset as well as in the final stage of platinum treatment. The ototoxicity pattern could not be identified for the different sexes in this study. The authors were able to develop a tool for early detection and monitoring of ototoxic damage, which also can be caused by recently introduced high dose cytostatic treatments and other experimental chemotherapeutic treatments in this study. They also recommended a reconsideration of the patient's cytostatic treatment in case of progression of a high frequency hearing loss (10000 to 18000 Hz) toward the low frequency range (<8000 Hz).

Dreschler, vander Hulst, Urbanus, (1989) applied high-frequency audiometry to compare the ototoxic effect of two different drug administration protocols for cis-platinum (CDDP). The scope of their study was to find:-

1) Effects of different CDDP treatments: 100 mg/m^2 administered in a 5-day protocol and 50 mg/m^2 administered in a one day protocol.
2) Effects of age and pre-existent hearing loss.
3) Possibilities for a reduction of the number of frequencies to be measured.
4) Increased sensitivity to detect ototoxicity damage by the use of high frequency audiometry.
5) Relation between the hearing loss in the conventional range of audiometric frequencies and high frequency losses.

238 ears from 119 subjects were studied. They were divided into three groups.

A -> 57 male subjects with five day treatment CDDP (mean age 29 years).

B -> 28 female subjects with five day treatment CDDP (mean age 51 years).

C -> 34 female subjects with one day treatment CDDP (mean age 57 years).

Pure tone thresholds were measured using an Interacoustics AC 5 audiometer with Telephonies TDH-39 head phones and Demlar HF audiometer with Koss HV/IA transducers. The thresholds found were expressed in dB SPL. All patients were treated at 3-week intervals with cis-platinum. The audiological examination took place within one week prior to each next treatment and 6 weeks and 3 months after the last treatment.

The results of the study are as follows:

Ototoxicity of different platinum treatments:

Table IV(4) shows the average thresholds at 1, 4, 8, 12 and 16 kHz for the first investigation before and after treatment for the subgroups of listeners in whom ototoxic damage was found. The major differences were present above 8 kHz. The results for the three subgroups are shown in Table IV(5). Two effects can be distinguished:

1) Groups A and B when compared shows the effects of age and sex. For older females a greater percentage of no-damage cases were found.

This difference appears to be due mainly to the reduced percentage of cases with high frequency damage. The final damage in the low frequency region is more frequent in the older females.

2) Taking groups B and C, the effects of the two treatments are compared in groups with comparable ages. The ototoxic damage in the group treated with the one-day treatment is significantly lower than in the group treated with the 5 day treatment.

Table IV (4): Average audiometric thresholds at selected frequencies

Frequency kHz	Respondents %	Average dB SPL before treatment total group	Average dB SPL before treatment impaired group	Average dB SPL after treatment impaired group
Group A				
1	100	10	9	8
4	100	19	18	21
8	100	25	24	31
12	99	37	35	55
16	95	73	70	90
Group B				
1	100	17	16	17
4	100	28	26	31
8	100	38	34	50
12	96	71	67	86
16	84	103	102	112
Group C				
1	100	17	16	17
4	100	31	29	35
8	100	43	41	53
12	97	83	83	94
16	91	114	113	115

Group A : Total group : 114 ears, 95 (83%) impaired ears; Group B : Total group: 56 ears, 36 (64%) Impaired ears ; Group C : Total group : 68 ears, 31 (46%) impaired ears.

Increased Detectability by the use of high-frequency audiometry:

Table IV(5) shows that the ototoxic damage has been found in a considerable percentage of ears, mainly because of the inclusion of the hearing losses above 8 kHz. The gain in detectability due to the use of high-frequency audiometry consists of the sum of cases in whom the ototoxic damage remained restricted to the high-frequency region and those in whom the damage started in high-frequency region. In 34-77% of the ears ototoxic damage was found in an earlier stage with high-frequency audiometry.

Table IV (5) Differences in the patterns of ototoxic damage found in 3 groups, treated with cis-piatinum (n=238 ears)

	Group A	Group B	Group C
No damage + fluctuating, %	17	36	54
Inital HF to final HF, %	55	23	24
Initial HF to final BF, %	22	29	10
Initial LF/BF to final LF/BF. %	6	12	12

High-frequency audiometry at one or two frequencies:

For the group of CDDP - treated subjects 12 or 14 kHz proved to be the best single frequency for the detection of ototoxicity: a 46% gain in detectibility can be found by measuring only at 12 or 14 kHz. It is remarkable that 14 kHz seems to be the best frequency for the younger group and 12 kHz for the older groups. This percentage increases only little when two frequencies are used. (Table IV (6).

Table IV (6) Percent gain (max. 59%) in sensitivity by measuring only one frequency (diagonal) or two frequencies (diagonal) above 8 kHz (n=238 ears)

	10 kHz	12 kHz	14 kHz	16 kHz	18 kHz	20 kHz
10 kHz. %	39	49	51	48	46	39
12 kHz. %		46	53	50	50	46
14 kHz. %			46	48	50	46
16 kHz. %				40	44	40
18 kHz. %					39	39
20 kHz, %						30

Dose-related effects for the low-and high-frequency regions:

In this study, groups A and B are combined as they receive the same treatment (Table IV(7).

Table IV (7): Differences in the patterns of ototoxic damage for all 238 ears, divided into two subgroups of ears : Group 1 with nondeviating pretreatment HF audiogram (n=170) and Group 2 with a deviating pretretment HF Audiogram (n-68)

	Group 1	Group 2
No damage + fluctuating, %	28	41
Inital HF to final HF, %	43	27
Initial HF to final BF. %	21	18
Initial LF/BF to final LF/BF. %	8	13

Fig. IV (14) shows as a function of the treatment number, (or cumulative dose) the percentage of ears in which a certain level of the damage severity index has not been reached. It shows clearly that at all levels of the damage severity index the percentages of unaffected ears decrease montonically with cumulative dose. It can also be seen that the high-frequency damage is present earlier than low-frequency damage. Comparable

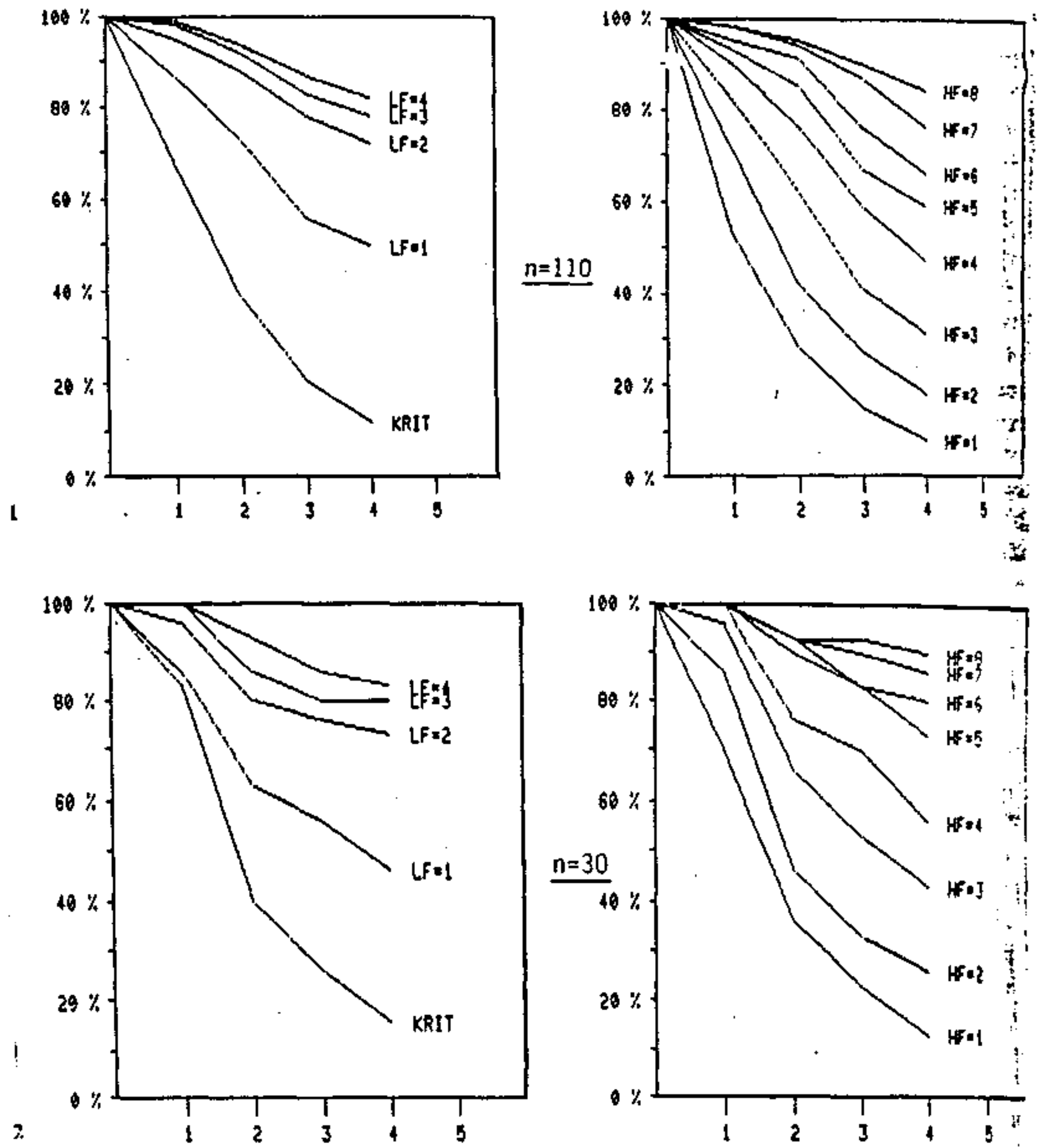


Fig IV (14). Percentage clears unaffected by ololoxic damage as a function of treatment number (related to cumulative dose) with the damage severity index as parameter. The left-hand panels show the patterns Ior the damage severity codes in the LF-region: the line LF=n shows the percentages of ears in which the severity code n was not reached in the LF-region. The 'overall criterion for ototoxieal damage is indicated by KRIT. Similarly, Thc resulls for the dntnngc sevtri codes in (he III-rcgion arc presentted in the rigs handl panels. I Subgroup of 55 subjects (110 etc which were treated with at least four 5-day trcatment (cumulative dose at least 400 mg/m^2. 2 Subgroups 30 cars with a deviating pretreatment HF audiograms which were treated with at least four 5-day tra merits.

curves for high-frequency and low-frequency damage have been found for a difference of about three to four classes, meaning that, on the average, the high-frequency damage is 15-20 dB severe than the low-frequency damage. In addition, it is obvious that in most cases the criterion for ototoxicity indicated in the figure IV (14) as KRIT is reached mainly due to high-frequency damage.

The conclusions of the study were:

1) High-frequency audiometry improves detection of platinum ototoxicity: thresholds at 12 and 14 kHz are particularly important.
2) Clear differences between treatments can be established by means of high-frequency audiometry.
3) High-frequency damage was present earlier than low frequency damage and was, on the average, 15-20 dB higher.
4) Pre-existing hearing loss changes the pattern but not the severity of ototoxic damage.

Fausti, Henry, Schaffer, Olson, Frey, McDonald, '. (1992) conducted a serial conventional (0.25 to 8 kHz) and high-frequency (9-20 kHz) hearing threshold monitoring prospectively in 53 hospitalized patients administered with aminoglycosides. Hearing loss occurred in 47% of the ears studied, with hearing loss first appearing in high-frequency range in 71% of ears showing change. Analysis of data on an individual basis reveals a five frequency range most susceptible to initial ototoxicity. Testing only this range would have resulted in early identification of 82% of ears showing change. Results confirm the critical need for serial auditory threshold monitoring encompassing high frequencies in patients receiving aminoglycosides. A shortened five frequency monitoring protocol is presented and suggested for use with patients unable to tolerate lengthy audiometric testing procedures.

Fausti, , Henry, , Schaffer, Olson, Frey, Bagby, .. (1993) investigated the ototoxic process as it relates to frequency regions that first show changes in auditory sensitivity in patients receiving cisplatin. They also designed a clinically practical monitoring protocol capable of reliably detecting ototoxicity. Twenty two hospitalized male patients with mean age 57.3 years receiving at least one infusion treatment with cisplatin were included in this study. The computer based audiometer [Model 320 (V320)] was chosen for this study with TDH-39 and Koss Pro/4X Plus transduces for the conventional and high-frequencies respectively. Results of this investigations demonstrated that hearing thresholds became poorer in 83.7% of ears studied. Hearing monitoring when restricted to 8kHz and above, 71.0% of these ears demonstrating hearing loss were identified and when monitoring was restricted to 8kHz and below, 54.8% of these ears were identified. (Fig. IV(15)) Thus the authors conclude that monitoring high-frequencies exclusively would provide earlier detection and a higher percentage of ototoxicity than monitoring only the conventional frequencies. By analysis according to an individualized, specific high-frequency range, early identification of hearing loss occurred in 94% of ears. They also recommended for a hearing monitoring protocol for patients receiving cisplatin. (ie) all patients should receive baseline audiometric evaluation consisting of frequencies from 0.25 to $20KH_z$. Monitoring of all

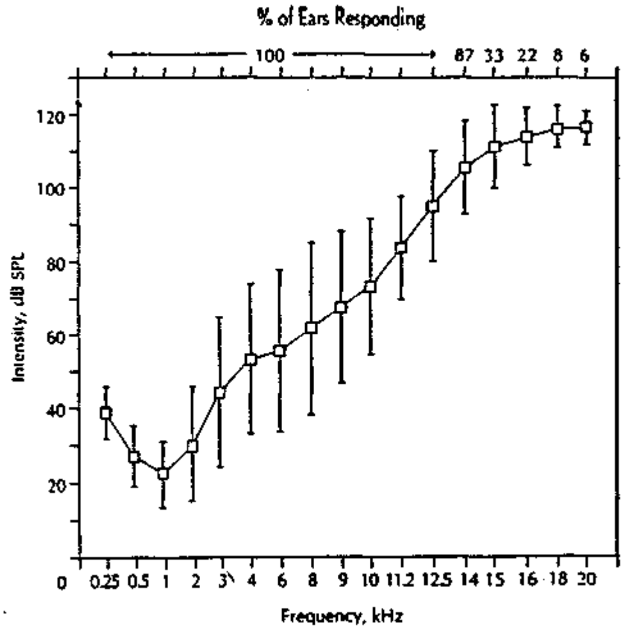
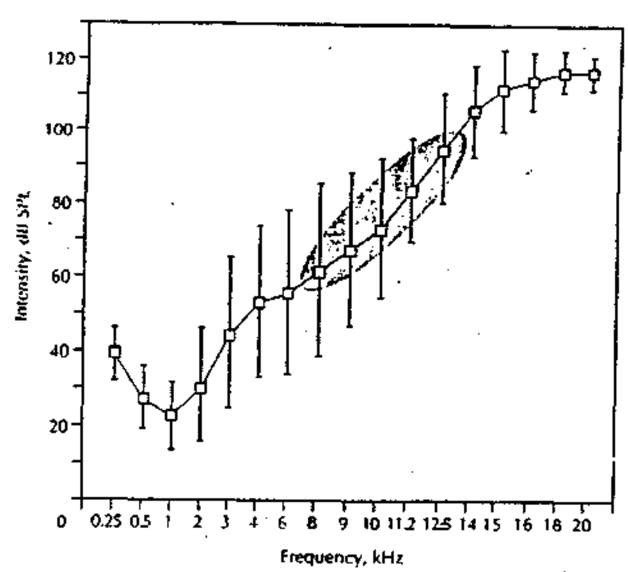


fig IV (15) baseline thresholds for 37 ears from 30 subjects treated with cisplalin. Numbers displayed on top of the figure indicate percentage of ears responding at each frequency. SPL indicates sound pressure level.



FigIV (16): *ve-frequency slope of hearing defined as the highest frequency from which each subject revealed a behavioral threshold of no greater than WO-dB sound pressure level (SPL) and including the next four lower consecutive frequencies.*

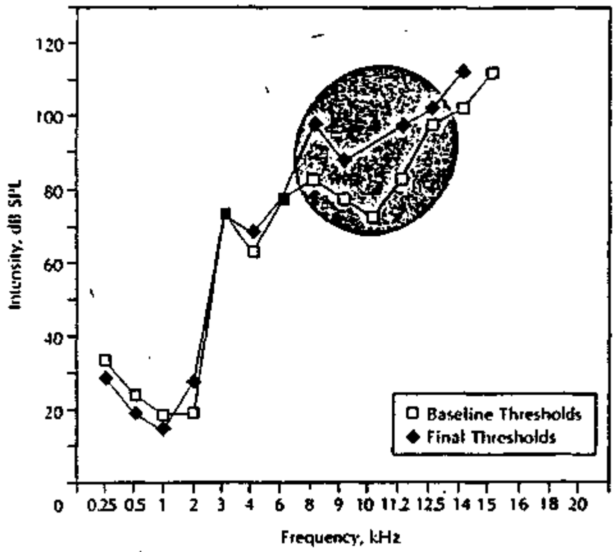
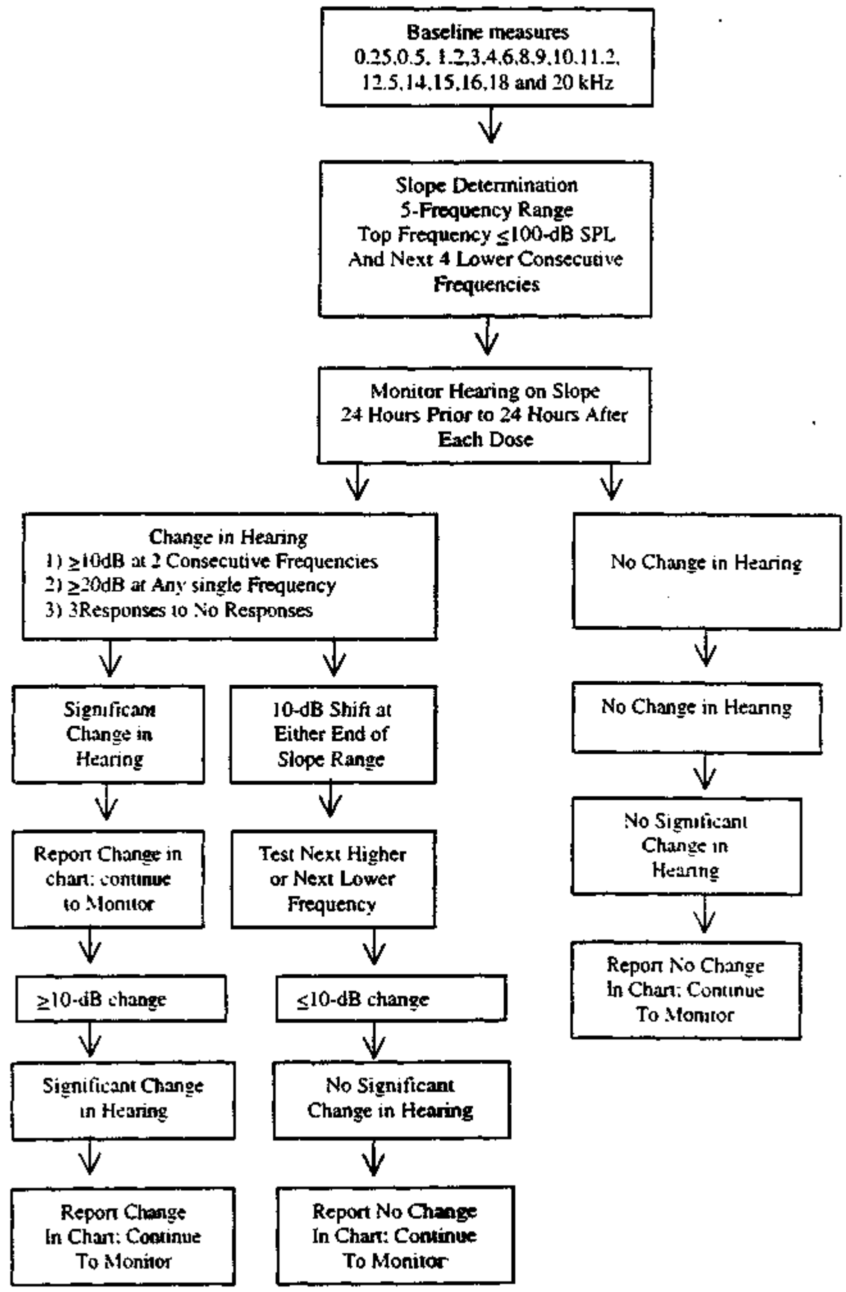


fig IV (17): *single subject's fix e-frequency slope of hearing at baseline and final lollow-up evaluations after receiving three doses of cisplatin. Change in hearing thresholds was specific to the slope of hearing. SPL indicates sound pressure lev el.*



Algorithm for alternate hearing threshold monitoring protocol for the treated with cisplatin who are unable to complete a full battery audiometric testing. SPL indicates sound pressure level.

measurable thresholds within the 0.25 to 20KHz range is done for maximum detection of ototoxicity. If length of the testing time is a factor, monitoring of the five frequency slope range was recommended. (ie) An attempt, to define a frequency range that will facilitate early detection of ototoxicity, analysis of each subjects threshold changes were conducted. These analysis were done by identifying the high-frequency slope of hearing in each subject. This high frequency slope of hearing was defined as a five-frequency range of hearing encompassing the highest frequency to which each ear revealed a behavioural thresholds of no greater than l00dB SPL and including the next four lower consecutive audiologic test frequencies. (Fig. IV (16) and Fig. IV(17)).

This five frequency range was used because data analysis showed that baseline high-frequency thresholds greater than l00dB SPL were observed to show minimal changes throughout a cisplatin treatment and monitoring protocol. (Fig. IV (18)). Adoption of this hearing monitoring protocol for patients receiving cisplatin treatment would be efficient and practical for routine clinical use. This protocol gives sensitive early detection of hearing loss, providing information for physicians to make alternative treatment decisions.

Domenech, , Cuchi, Fuste, Traserra-Coderch. (1993) conducted a study on the possible ototoxicity of josamycin by high-frequency audiometry. There have been no reports of ototoxic effects caused by this drug, but its similitudes with erythromycin have prompted the authors to conduct the study about its possible cochleartoxicity. 28 patients without previous auditory impairment were studied with conventional (upto 8,000 H_z)

and high-frequency audiometry (upto 20,000 H_z) before and after oral treatment with josamycin during eight days. No significant differences were found in auditory threshold registered before and after treatment in any of the patients. These results suggest that josamycin is devoid of any cochleo-toxic effect in all the frequencies that a normal subject can hear.

Noise induced hearing loss:

Occupational noise - induced hearing loss (NIHL) is extremely common. Pure-tone air-conduction audiometry in the conventional frequency range through 8kHz is the standard method of recording hearing thresholds in noise exposed subjects. Since the demonstration of significantly lower air conduction thresholds above 8kHz in the African Mabaans compared with age matched western controls (Rosen et al 1964), several authors have hypothesized that noise induced hearing loss may be detectable at an earlier stage by extended high-frequency (EHF) audiometry (Osterhammel (1979), Fausti et al (1981): Dieroff (1982). Elevated extended high-frequency air-conduction thresholds have been reported in paper mill workers, the average differences between noise- exposed and non-noise exposed employees being around 19dB for each frequency tested (Sataloff et al 1967). Raised extended high-frequency thresholds have also been documented in noise exposed high-school students (Corliss et al, 1970) and adult population (Flottorp 1973). Additionally, low-frequency, below 0.5 kHz exposure has been reported to produce temporary thresholds shift at considerably higher frequencies, both in the region of the classical noise, induced hearing loss dip around 4 kHZ, but also in the extended high-frequency range at 10-11 and 14-15 kHz (Fritze and Kohler 1985). On the other hand, Osterhammel (1979) found threshold preservation in noise-exposed subjects, especially in the upper extended high-frequency range.

Acute acoustic trauma following exposure to impulse noise is characterized by considerable threshold elevation in the extended high frequency range, with extension also into the conventional frequency range (Fausti et al (1981), Dieroff (1982). Hanner and Axelsson (1988)).

There is still some uncertainity in the literature as to whether intra-operative noise exposure during ear surgery can result in either temporary or permanent hearing loss. The cochlea in both the operated and the contralateral ears may be exposed to considerable noise levels during surgery for chronic ear disease. Mastoid drilling, for example, has been shown to produce noise levels of around l00dB (A) (Kylen and Arlinger, 1976: Holmquist et al,1979: Hickey and O'Connor,1991), whilst suction irrigation may produce even more intense noise than drilling (Parkin et al. (1980), Wetmore et al (1993)).

Temporary threshold shift for bone-conduction in the frequency range upto and including 8 kHz has been demonstrated by electrocochleography immediately after drilling during ear surgery (Kylen et al 1977). It has been demonstrated experimentally that drilling on the ossicular chain can result in transmission of noise levels of at least 130dB(A) to the inner ear (Helms, 1976). Sensori-neural hearing loss has been reported in 10 of 65 ears in which simple or modified radical mastoidectomy was performed. (Palva and Sorri, 1979). There has been no evidence of hearing loss in the contralateral ears in a series of 50 consecutive patients in whom translabyrinthine removal of an acoustic neuroma was performed, a procedure which entails more prolonged drilling than a mastoidectomy (Tos et al, 1989). Elevation of air conduction extended high frequency thresholds after myringoplasty and stapes surgery was first described by Mair and Laukli (1986).

Morton, and Reynolds, (1991) investigated the effects of age and noise exposure. 97 normal subjects representing six age groups were tested with both conventional pure tone audiometry and high frequency (10-20 kHz) using a commercial high frequency audiometer. Thresholds were obtained by means of earphones as opposed to a quasi free field technique. The results were discussed in terms of the age effect. In addition, conventional and high frequency thresholds were obtained for 64 subjects who had history of noise exposure representing four age groups. Significant differences were found between the noise exposed group and normal subjects.

Hallmo, Borchgrevink, Mair, (1995) measured the air conduction and bone conduction thresholds in the conventional audiometric frequency ranges, and air conduction alone in the extended high frequency range of 9-18 kHz in 167 males with a history of occupational noise exposure. (Table IV (8)). Madsen OB 70 matched with TDH 39 ear phones and Inter acoustic AS10HF matched with Koss HV/1A earphones were used in the conventional and extended high frequency ranges respectively. Narrowband noise and 1/3 octave filtered white noise geometrically centered at the frequency of the test tone was employed for masking in the conventional and extended high frequency ranges respectively.

Table IV (8): Number of subjects in each age group together with mean number of years of employement in a environment.

Age group	No.	Mean Exposure year
18-24	32	3
30-39	26	11
40-49	50	20
50-59	59	26

Table IV(9): Numbers of ears and subjects, bracketed the 4 age groups and grades of CF, NIHL. The total numbers refers to ears.

	Grade CF NIHL				
Age group	I	II	III	ΙV	TABLE
18-24	37(26)	15(12)	4(4)	0	56
30-39	19(12)	17(12)	11(8)	2(1)	49
40-49	25(19)	32(26)	25(18)	5(4)	87
50-59	27(20)	34(29)	36(27)	15(10)	112
Total	108(77)	98(82)	76(57)	22(15)	304

Table IV (9) gives the numbers of both subjects and ears with NIHL grades I-IV in the four different age groups. The severest form of noise induced hearing loss, grade IV did not occur in the youngest age group, affected 13% of ears in the oldest group, and was present in less than 5% of the groups aged 30-39 and 40-49 years. There was no significant tendency within age groups for subjects with severer grades of noise induced hearing loss to have longer noise exposure times (Table IV(10)).

Table VI (10): Mean numbers of years of employement in a noisy environment for each grade of CF NIHL in the four age groups.

Age group	Grade CF NIHL I	II	III	IV
18-24	3	4	3	
30-39	9	14	16	20
40-49	20	19	29	21
50-59	22	28	26	25

Median thresholds for the four age groups are shown for each grade of noise induced hearing loss in Figs IV (19) and Fig. IV (20) respectively for the conventional frequency and extended high-frequency ranges.

Threshold elevation is evident in the extended high-frequency range in the youngest, 18-24 year age group with the lowest grade (Fig. IV 20 (i) grade I, of noise induced hearing loss in the conventional-frequency range (Fig. IV 19 (i)) and is approximately 20dB at all frequencies from 8 through $18KH_Z$ Whereas the four different age groups show, by definition, comparable conventional frequency thresholds in all four grades (Fig. IV (19)), extended high-frequency overlapping is found only for the age groups in grade III. In grade I, (Fig. IV 20 (i)), there is no overlapping in any of the age groups.

Elevation of air-conduction thresholds in noise induced hearing loss occurs both at 3-6 kHz and throughout the extended high-frequency range of $9\text{-}18KH_Z$. Extended high-frequency thresholds are of the same order of magnitude for all age groups in the more severe grades of conventional frequency noise induced hearing loss. The younger age groups maintain a

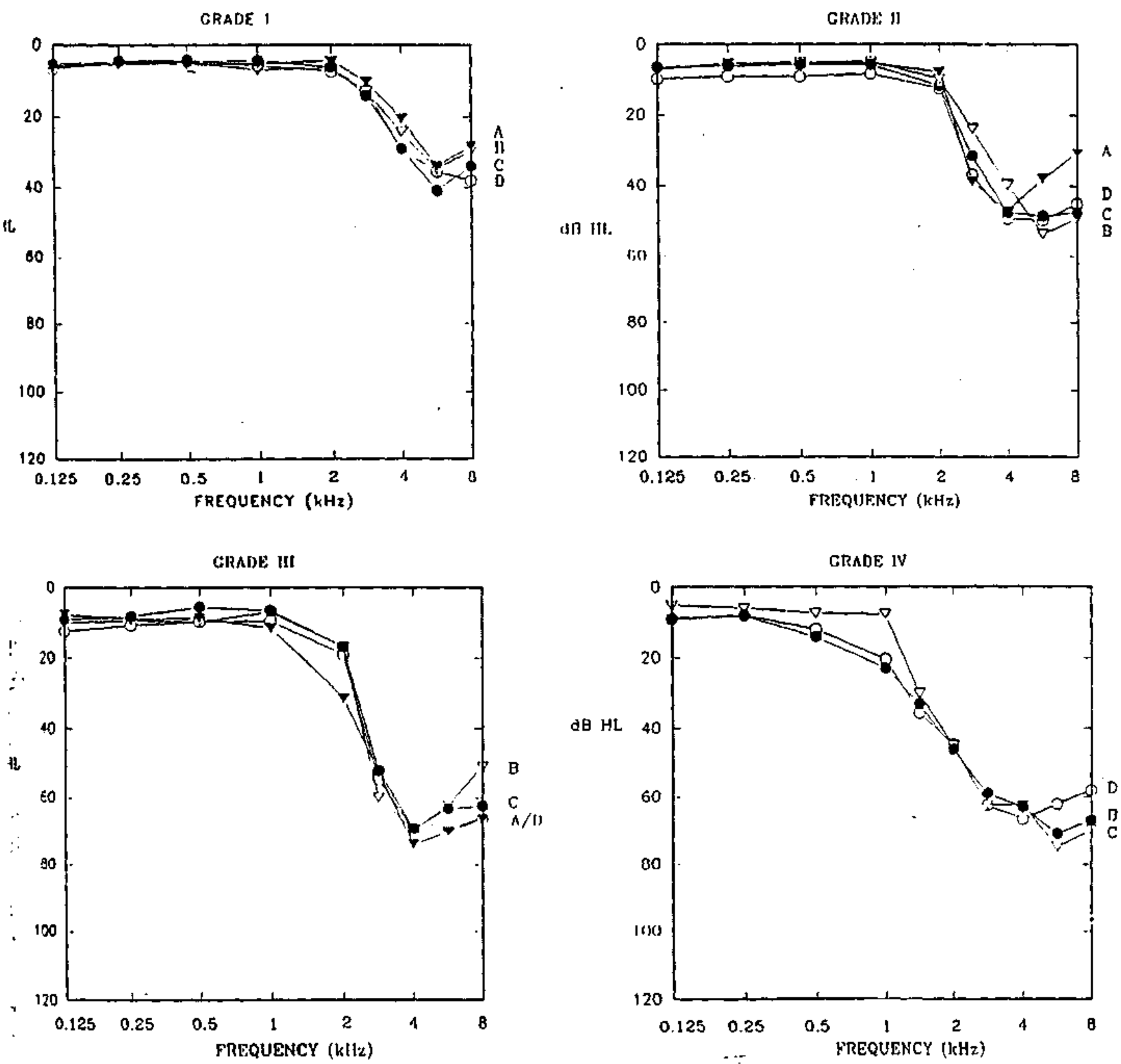


Fig Iv (19)Median AC CF thresholds for grades I through IV in the four different age groups. In these and subsequent figures the lowing symbols are used: 18-24 years—A/fillcd triangle; 30-39 years—B/open triangle; 40-49 years—C/fi!1ed circle; 50-59 rs—D/open circle.

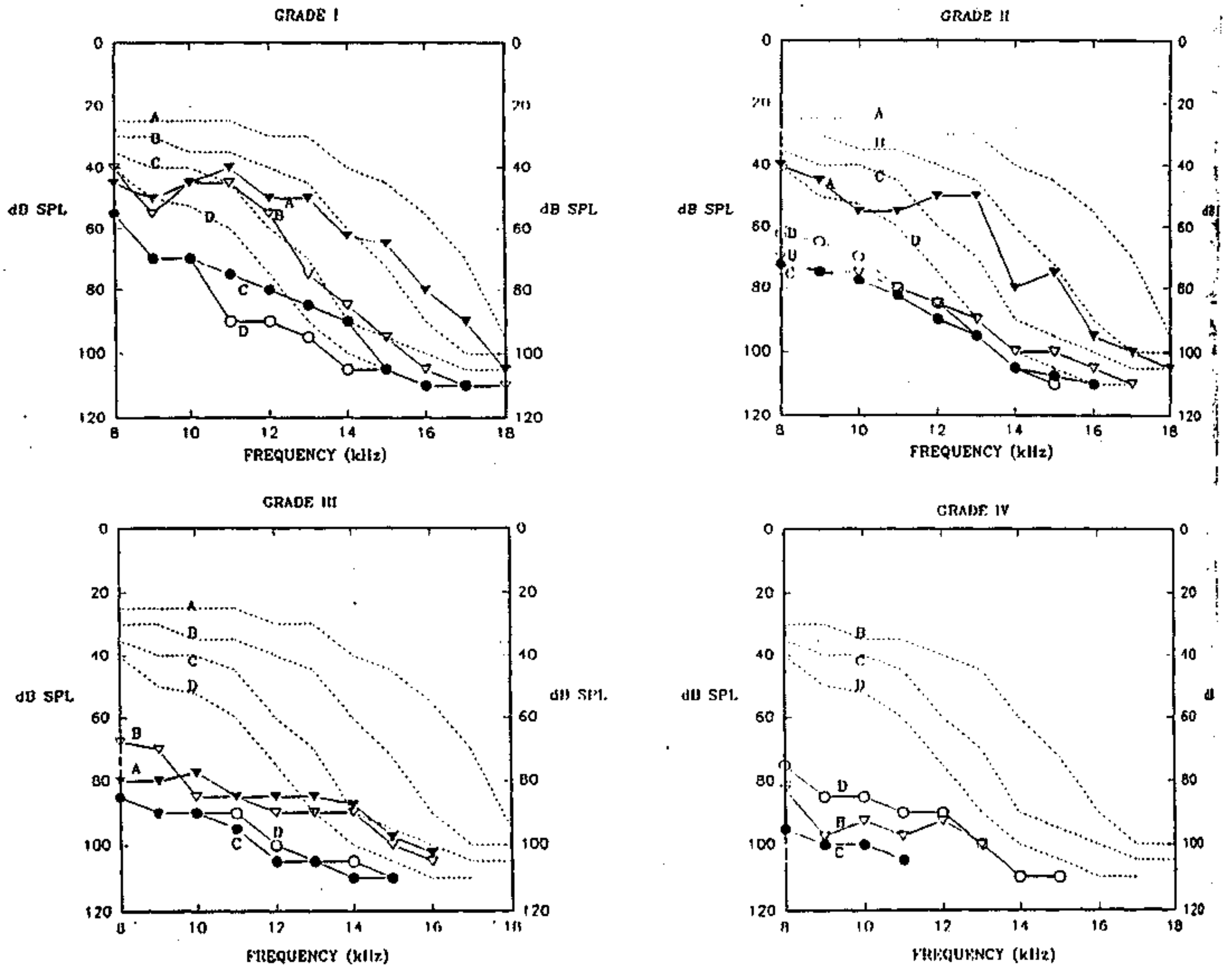


Fig IV (20): Median AC EHF thresholds for grades I through IV in the four different age groups. Thresholds are also show the same age groups from this laboratory's 'normal' population. Note that the frequency scale is linear and the ordinate dB SPL.

extended high-frequency threshold superiority in the lesser grades of convention frequency noise induced hearing loss.

Hallmo, . and Mair, (1996) recorded bone-conduction thresholds in the extended high-frequency ranges before and after middle ear surgery in which drilling was performed and compared them. 45 subjects (18 females and 27 males) with an age range of 7 to 46 years in whom 46 procedures were performed were taken. The type and number of procedures are given in Table IV (11).

Table IV (11): Number of surgical procedure

Procedure	No
Attico-antro-mastoidectomy	16
Attico antrotomy	11
Radical mastoidectomy, repeat	6
Radical mastoidectomy.	5
Tymphanomastodectomy,	4
Cortical mastoidectotny,	3
Removal osteoma,	1
Total	46

Madsen OB70 with B71 bone vibrator and Inter-acoustics AS10HF audiometer with Pracitronic KH 70 bone vibrator were used to measure conventional frequency and extended high-frequency ranges respectively and the earphones used were TDH 39 with MX 4/AR cushions at conventional frequency range and Koss HV/1A earphones at the extended high-frequency range. Masking was done using narrow band noise and 1/3 octave filtered white noise geometrically centered at the frequency of the test tone for the conventional and extended high-frequency ranges respectively.

Air-conduction and bone-conduction thresholds in conventional frequency and bone-conduction in extended high-frequency determined the day before and again 3 months after surgery. For 15 subjects the extended high-frequency audiometry was done on contralateral ear.

Table IV (12): Differences between post and pre-operative BC Thresholds at each frequency, mean and standard deviation (SD) and number of ears (n). Operated ear A positive value indicates postoperative threshold deviation.

Frequecny (kHz)	Mean(dB)	SD(dB)	n
0.25	1.2	12.2	31
0.5	0.7	7.9	31
1	1.0	7.5	31
2	-1.2	5.3	31
3	0.0	10.5	31
4	1.1	11.2	31
8	0.9	8.5	46
9	1.1	9.0	46
10	1.0	9.9	46
11	0.3	11.0	46
12	0.9	10.5	41
13	3.3	12.3	38
14	2.5	12.5	36
15	1.7	8 8	29
16	0.8	9.1	24

Table IV (12) shows the mean and standard deviation of the differences between the pre-and post-operative bone-conduction thresholds for each frequency. The number of responding ears in extended high-frequency decrease with frequency due to the frequency dependant dynamic range of the Pracitronic vibrator. The values both in conventional frequency except for 2 and 3KHz at which a 1:1 dB improvement and no change were found respectively, and in extended high-frequency are all positive, but none achieves statistical significance. The mean change for the entire octave of 8-16 kHz is l.'4dB, which is marginally significant (P=0.02). BC threshold changes for the contralateral ears are shown in Table IV (13), and reveal slight threshold improvement for the frequencies 8 through 11kHz, and comparably deteriorates at 12 through 14kHz this being some what greater at both 15 and 16kHz. None of these is significant, nor is the mean change of 0.5dB for the octave 8 through 16kHz.

Table IV (13): Differences between post-and pre-operative BC Thresholds at each frequency, mean and standard deavieation (SD) and number of ears (14). Contralateral. non-opereted ear. A Dositive value indicates DOStODeratives threshold deviation.

Frequecny (kHz)	Mean(dB)	SD(dB)	n
8	-1.3	5.3	15
9	-1.7	4.3	15
10	-0.7	5.1	15
11	-1.3	5.6	15
12	0.7	6.5	15
13	0.4	6.7	14
14	1.4	5.8	14
15	3.9	9.3	14
16	2.7	6.9	1 1

There was no statistically significant post-operative threshold change at any single frequency in either the operated or the contralateral ear. The mean threshold elevation of 1.4dB for the ipsilateral extended high-frequency octave of 8-16 kHz was marginally significant (P=0.02), while this was not the case in the contralateral, unoperated ear. These findings are considered to be due to difficulties in placement of the cumbersome Pracitronic KH70 vibrator following bone removal ipsilaterally, with resultant defective transmission to the skull. Earlier studies purporting to have demonstrated extended high -frequency threshold deterioration after drilling are methodologically flawed due either to lack of masking of the opposite ear (Domenech et al, 1989: Hegewald et al 1989) or lack of bone-conduction measurements (Verbist et al 1993).

Miscellaneous

High-frequency audiometry has been used for investigating various other disorders such as otosclerosis, tinnitus, obscure auditory dysfunction, diabetes presbyacusis, etc. We shall see a few studies concerned with this.

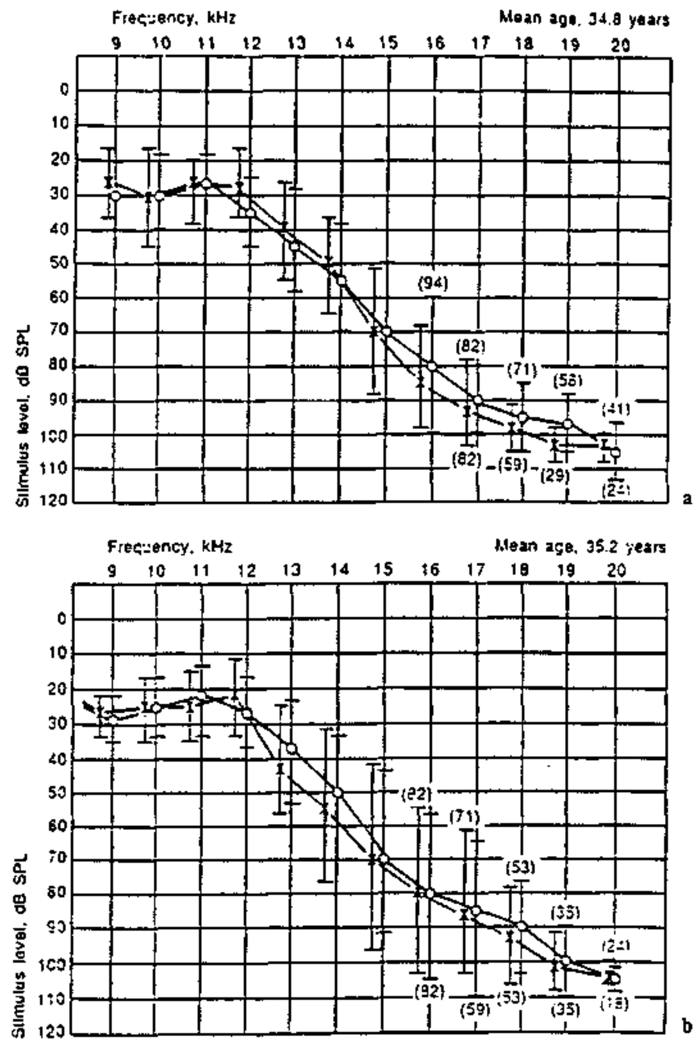
Tinnitus is usually associated with hearing losses of various origins (Chaba; in Tonndorf and Kurman, 1984), for example tinnitus often accompanies a noise induced hearing loss, (8% of the subjects with tinnitus have normal conventional audiograms (0.25-8kHz)). The majority of these subjects have a history of exposure to high-intensity occupational noise.

Barnea, Attias, Gold, Shahar, (1990) investigated whether extended high-frequency audiometry might show significant differences between subjects with or without tinnitus but with normal hearing sensitivity. Two groups of subjects with normal hearing were taken. One group consisted of 17 subjects with tinnitus and the other without tinnitus. Extended high-frequency audiometry was done with a Demlar Model 20K extended high-frequency audiometer with Koss Model HV/1A earphone.

Fig. IV (21) shows the average extended high-frequency audiograms for both groups including the percentage of subjects that responded at each frequency. No significant differences were found between the two groups or between the right and left ears, either in terms of mean thresholds across the frequency range from 9 to 20kHz or frequency distributions. However, when each frequency was considered separately, the means of 12kHz were found to differ significantly between the right and left ears in both the experimental group ($t=2.84$, $P<0.005$) and in the control group ($t=1.81$, $P<0.005$). A subgroup of the experimental group consisting of nine subjects who reported relatively more severe tinnitus were compared to the control subjects on extended high-frequency audiometry. Only two frequencies, 12 and 13 kHz, differed significantly between the two groups in the right ear only ($t=2.13$, $P<0.05$; $t=2.21$, $P<0.05$). Although not significant, the percentage of subjects that responded at the extremely high frequencies (from 16 kHz) was unexpectedly slightly higher in the subjects with tinnitus. It is concluded that the results of extended high-frequency audiometry showed no significant differences between the subjects with and without tinnitus.

Tange, Dreschler, (1992) carried out a study to evaluate the value of high-frequency audiometry in stapes surgery in cases of otosclerosis. The hearing function was measured pre-and post-operatively by

Fig IV (21): Extended HF audiograms tor the two groups. The numbers in brackets represent the percentage of subjects that responded at the higher frequencies, if not indicated, then all the subjects responded at that frequency, a Normal hearing sensitivity with tinnitus, b Normal hearing sensitivity without tinnitus.



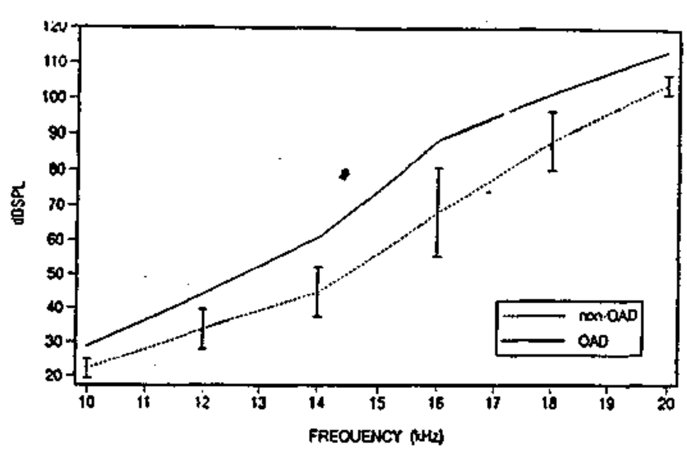


Fig IV (22) Mean HFA thresholds for the experimental (OAD) and control (non-OAD) groups between 10 and 20 kHz. Vertical bars represent 1 standard deviation.

means of conventional-and high-frequency audiometry (Demlar 20K). The operative findings of the gradations of otosclerosis were compared with the pre- and post-operative high tone audiogram and gradation of otosclerosis. In conclusion, it is stated that high-frequency audiometry can predict the state of stapes fixation in otosclerosis and that can be important in stapes surgery.

High-frequency hearing acuity has been shown to be essential for temporal resolution measured by gap detection tasks (Moore 1985). Literature suggests that upward spread of masking in patients with high-frequency hearing loss could results in poor speech discrimination (Kiukaanniemi 1980, Tyler et al. (1982). It could be hypothesied that poor speech perception in obscure auditory dysfunction could result from a ultra-high frequency hearing loss and the subsequent masking of any speech information that may be carried above 8kHz.

Shaw, Jardine, Fridjhon, (1996) conducted a pilot study on a small sample of obscure auditory dysfunction (OAD) subjects in order to establish whether there was a difference between their results on high-frequency audiometry when compared with those of their matched control. Nine OAD subjects falling within the age range 15-55 years with complains of discriminating speech in noise and 18 matched controls were selected from the general public by their negative OAD status, were taken for the study. Beltone 2000 high frequency audiometry with HD-250 linear earphones was used for testing. Thresholds were established between 10kHz and 20kHz using a modified Hughson - Westlake procedure as described by Stelmachowicz et al. (1989). The mean high-frequency audiometric thresholds of the experimental and control groups are as presented in Fig. IV(22). The

OAD subjects high-frequency audiometric thresholds were elevated for the frequencies 10-20 kHz. Furthermore, the difference between the experimental and control group at 18kHz and 20kHz is greater than that illustrated on the graph as some OAD subjects' high-frequency audiometric thresholds exceeded audiometer limits and were therefore recoded as 120dB. Thus the results revealed that there was elevated threshold amongst all frequencies (10-20 kHz) in OAD patient with significant differences occurring at 10, 14, 16 and 20 kHz. It could be postulated that OAD in fact, is the product of an ultra - high-frequency hearing impairment and its psychoacoustic sequelae. Furthermore high-frequency audiometry may be a useful inclusion in a diagnostic test battery for OAD status. However the degree to which it can be used may be limited due to the large inter-subject variability in high-frequency audiometric thresholds in the normal population.

Hallmo, P. (1997) documented the possible effects of the injury due to traumatic tympanic membrane perforations (TTMPs) on the inner ear and on sound transmission in the extended high-frequency range, and relate the extended high-frequency data to audiometry in the conventional-frequency range.

Thirty eight patients (19 males and 18 females) with unilateral traumatic tympanic membrane perforation were taken as subjects for the study. Median age was 28 years. The mechanisms of the injury were blow to the ear, water sports, water pressure against ear, penetrating injury and fire works. The instruments used in the study were Madsen OB70 in the conventional frequency (0.125-8kHz) and Interacoustics ASIOHF in the extended high-frequency (9-18kHz) ranges through matched TDH 39 earphones with MX 41/AR cushions and Koss HV/1A earphones respectively. In the bone-conduction studies, the same tone generators activated the B71 bone vibrator in the conventional frequency. (0.25-4kHz) and Pracitronic KH 70 in the extended high-frequency (8-16kHz) ranges respectively. Making noise for both air-conduction and bone-conduction was narrow band noise and 1/3 octave filtered white, noise geometrically centered at the frequency of the test tone for conventional-frequency and extended high-frequency respectively. The validity of the masking procedure in the extended high-frequencies had been confirmed in the earlier study given by Hallmo et al (1992).

Results of the study showed that there was sensorineural elevation found in 16 ears. Both the sensorineural threshold elevation and tinnitus diminished with time. A temporary, mean 5 dB, bone-conduction threshold elevation $\geq$ 8kHz was seen in 26 ears following spontaneous tympanic membrane closure. (Table IV (14)). Closure resulted in a 7 to 20dB improvement of air-conduction thresholds in the 0.125 kHz to 18 kHz range, somewhat less in the upper than the lower frequencies. (Table IV (15)). A3 dB mean final conductive hearing loss greater than 8 kHz was found in the 26 ears approximately five months after injury, probably due to scars in the pars tensa at the site of the former perforations.

Table IV(14): Mean BC threshold gain in dB, standard deviation (SD) and number of ears (N) responding for the different EHFs (kHz), following spontaneous TM closure

kHz	Mean	SD	n
8	-3.3	5.6	23
9	-3.9	4.7	23
10	-4.6	6.9	23
11	-4.5	8.5	22
12	-4.8	7.9	22
13	-6.0	8.0	21
14	-5.8	6.1	18
15	-4.4	6.8	16
16	-4.2	4.7	13

Table IV(15): Mean AC threshold gain in dB, standard deviation (SD) and number of ears (N) responding for the different frequencies (kHz) after spontaneous TM closure

kHz	Mean	SD	n
0.125	20	9.8	26
0.25	19	12.1	26
0.5	15	10.4	26
1	16	8.4	26
2	16	9.0	26
3	14	8.7	26
4	12	9.4	26
6	10	12.9	26
8	10	11.0	26
9	12	13.5	26
10	12	10.7	26
11	11	12.4	26
12	11	13.6	26
13	12	13.8	25
14	10	12.2	25
15	10	12.5	24
16	10	10.1	23
17	9	8.2	20
18	7	7.5	17

Part of the extended high-frequency sensorineural improvement might be due to transmission improvement accompanying closing of the tympanic membrane. A temporary, mean 5dB extended high-frequency bone-conduction threshold elevation before tympanic membrane closure indicates that normal extended high-frequency transmission depends on a normally functioning tympanic membrane.

HIGH PROBE FREQUENCY
(HIGH FREQUENCY IMMITANCE AUDIOMETRY)

Acoustic reflex measures at high-probe-frequencies (above 660Hz) have not been extensively reported in the published literature. Studies of the acoustic reflex at low-probe-frequencies conflict as to the effect of the reflex on resistance, although all researches agree that the reflex increases the amount of negative reactance (stiffness). These differences may reflect methodological differences across studies. Lutman and Martin (1979), Lutman et al (1984) have used phasor diagrams to provide evidence for the effect of the reflex being on reactance, with constant resistance for low-probe-frequencies. (220 and 660Hz).

Reynolds, and Morton, (1995) incorporated the use of the phasor diagram approach to investigate the effect of the reflex at a l000Hz probe frequency. 30 subjects with normal young ears were taken for the study. The 30 ears used in this study had a mean resonance frequency of 940Hz (range: 450-1400 Hz). Ten of the ears were stiffness dominated at the l000Hz probe frequency. Eight were at resonance and 12 ears were mass dominated according to the Vanhuyse et al (1975) tympanometric classification. Immitance measures were made using the GSI-33 version 2 Middle Ear Analyser. The probe frequencies (including l000Hz) are nominally set to 70dB HL. Ipsilateral reflex probe and stimulus tones are alternated.

Reflex measurements were obtained ipsilaterally at the l000Hz probe frequency using three stimulus frequencies (500 1000 and 2000Hz). Stimulus intensity ranged from levels below expected reflex thresholds (66dB HL) to the maximum output of the GSI 33 (110 dB HL for 0.5 and 1kHz and 104dB HL for 2kHz). Stimulus duration was kept constant at 1.5sec each stimulus presentation.

Susceptance and conductance values were recorded and were presented as phasor diagrams. Three phasors, representing each of the stimulus frequencies used in the study, were obtained for each subject. The resulting phasor diagrams were examined for :

1. Circular shape passing the origin to represent a constant resistance (resistance being represented by the radius of the circle):
2. Anti-clockwise movement along the circumference of the circle, to indicate an increase in stiffness during the activation of the acoustic reflex.

Phasor plots those fits with these criteria were considered to indicate a constant-resistance stiffness change pattern. Phasors were labelled either as classifiable within the model, or as unclassifiable. The phasor plots were analysed qualitatively, because quantitative analysis through summary statistics may have obscured the patterns obtained. The classification of the phasor plots was shown in table form (Table V (1)). The obtained shape of the phasor diagrams and baseline values were related to the theoretical model presented by Lutman (1984).

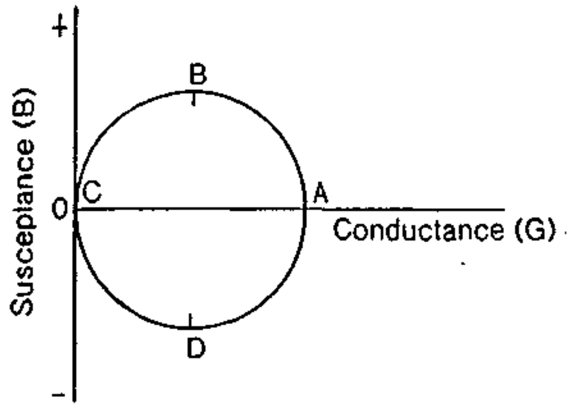
Table V (1): 1. Classification of phasor diagrams

Classification	Baseline transmission					
	Resonance frequency			1000 Hz tympanometric configuration		
	n	Mean (Hz)	Range (Hz)	IBIG	3BIG	3B3G
Classifiable (Freverted) U shape	34	1100	500-1400	15	17	2
Classifiable (Onverted) C shape	40	907	650-1300	15	7	18
Classifiable Ushape	8	680	650-700	0	0	8
UC lassifiable	g	600	450-750	0	0	8

In this study 90 phasor plots were obtained. Those phasor plots that were classified as circular were related to a particular portion of the circle. (Fig. V (1)) The portion of the circle over which the trajectory occured was marked as either U-shaped, inverted U shaped, or reversed C-shaped as shown in Fig.V (1). 82 of the 90 phasor obtained were classifiable. The other 8 were unclassifiable.

The classifiable phasor were divided into the portion of the circle over which they traversed, and this was closely related to their baseline transmission properties. That is, the starting point of the classifiable phasors could be placed in the portion of the circle as determined by baseline functioning. Examples of each type of classifiable phasor is provided in Fig. V (2,3,4).

The unclassifiable phasors were all obtained from ears that were mass-dominated,but mass dominated ears also yielded a large number of



Key

Point A:	Represents the natural frequency of the system
Trajectory A - C :	Inverted U shaped phasor plots.
Trajectory C - A :	U shaped phasor plots.
Trajectory D - B :	Reversed C shaped phasor plots.

Fig V (1).Schematic representation of phasor diagrams obtained which fit wiih the constant-resistance stiffness-change model

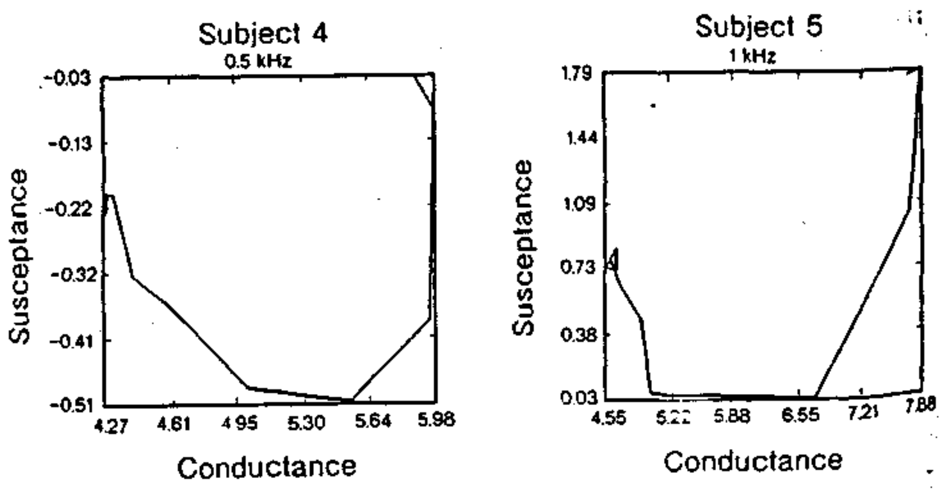


Fig V(2): Examples of U-shaped phasor plots

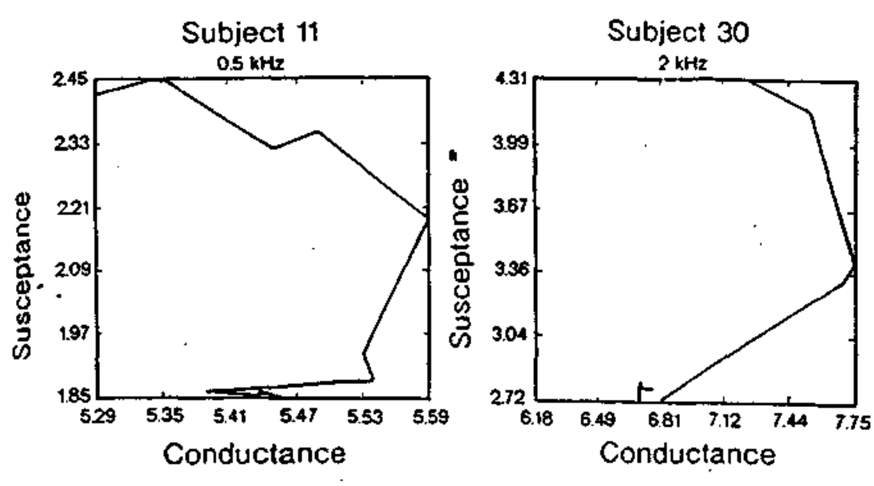


Fig V 2(3) Examples of reversed C-shaped phasor plars

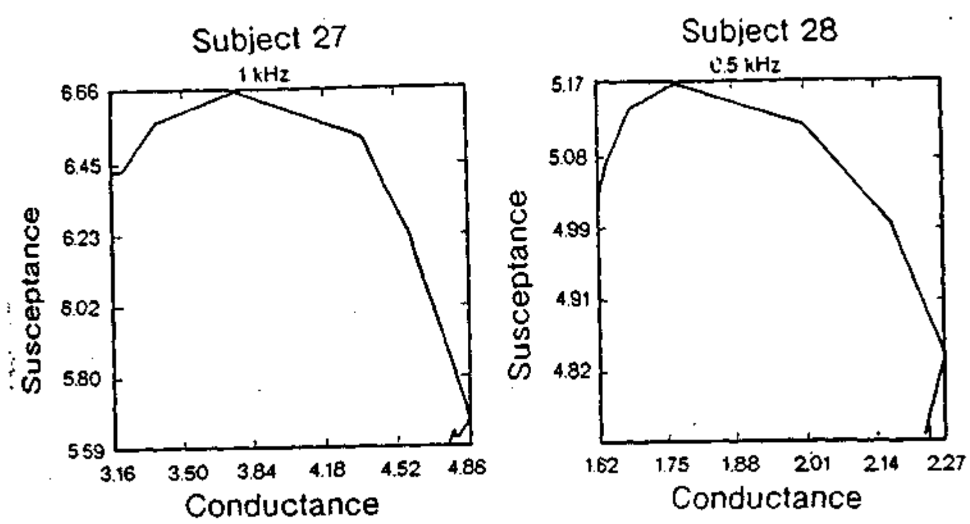
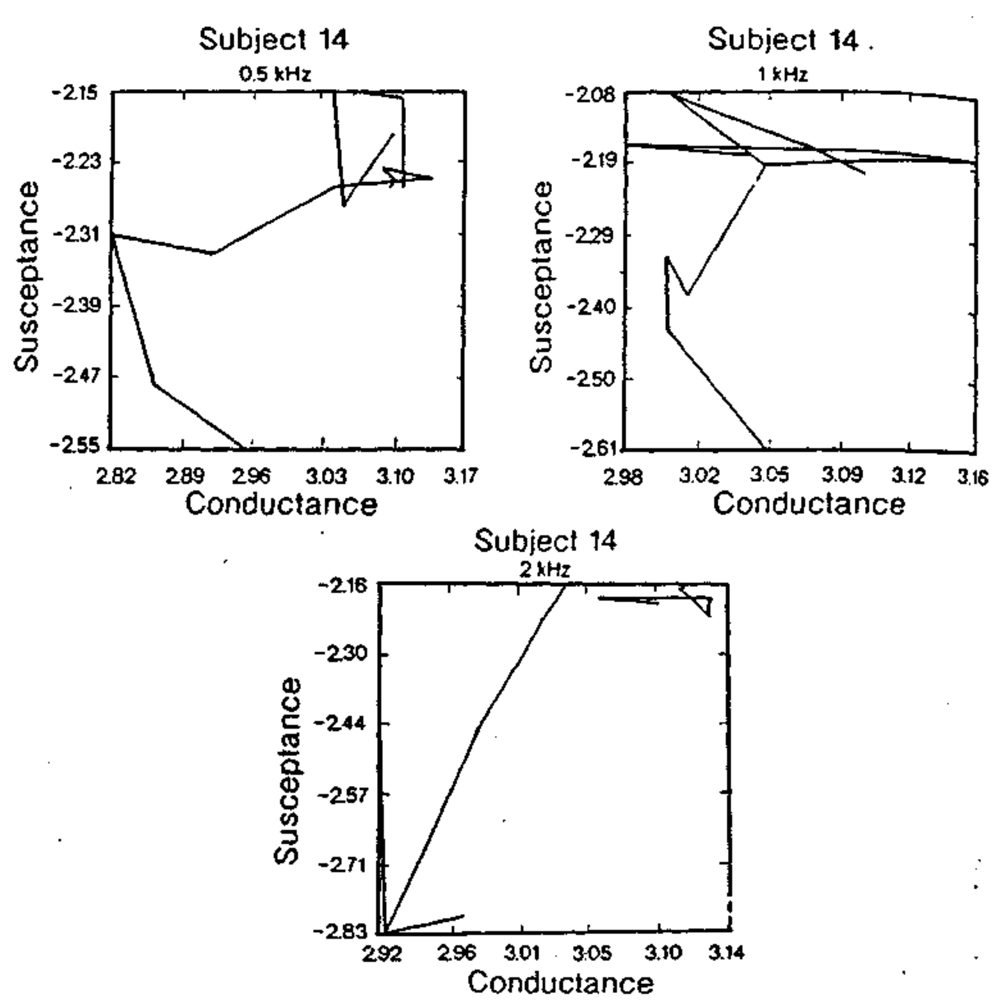


Fig V (4)Examples of inverted U-shaped phasor plots



FigV (5):Examples of phasorplots which are not circular classifiable phasors, and so a clear pattern is not evident. The eight un classifiable phasors are all displayed in (Figs V (5 and 6)).

The three phasors shown in Fig V (5) are not circular and the effect of the reflex is not possible to establish for this ear using the phasor representation. These three growth functions were all obtained from a single subject, and like other ears showing unclassifiable phasor plots, had mass dominated transmission properties in the baseline condition. It is possible that the mass domination was more marked for this subject as compared with other subjects, but apart there is no differentiating feature between this ear and other ears used in this study.

The remaining unclassifiable phasors shown in Fig V (6) were, representative of clockwise movement along the trajectory (subjects 7 and 11), suggestive of a decrease in stiffness (Lutman and Martin 1979) and poorly represented effects on resistance. The phasors obtained from subject 9 were also difficult to match to a circular are, but were possibly influenced by a large number diphasic reflexes, for whom the centre point was used to plot the phasors, and this may in some way have obscured the pattern.

The results indicate that while the majority of growth functions displayed as phasor plots in the present study for a high (l000Hz) probe frequency indicate an increase in stiffness with constant resistance, there are some phasors obtained from mass dominated ears for which this pattern is not evident. The actual effect of the reflex for these ears was not identifiable using the phasor representation form of analysis.

The authors conclude that the effect of the reflex on transmission characteristics of the middle ear were shown to be consistent with previous

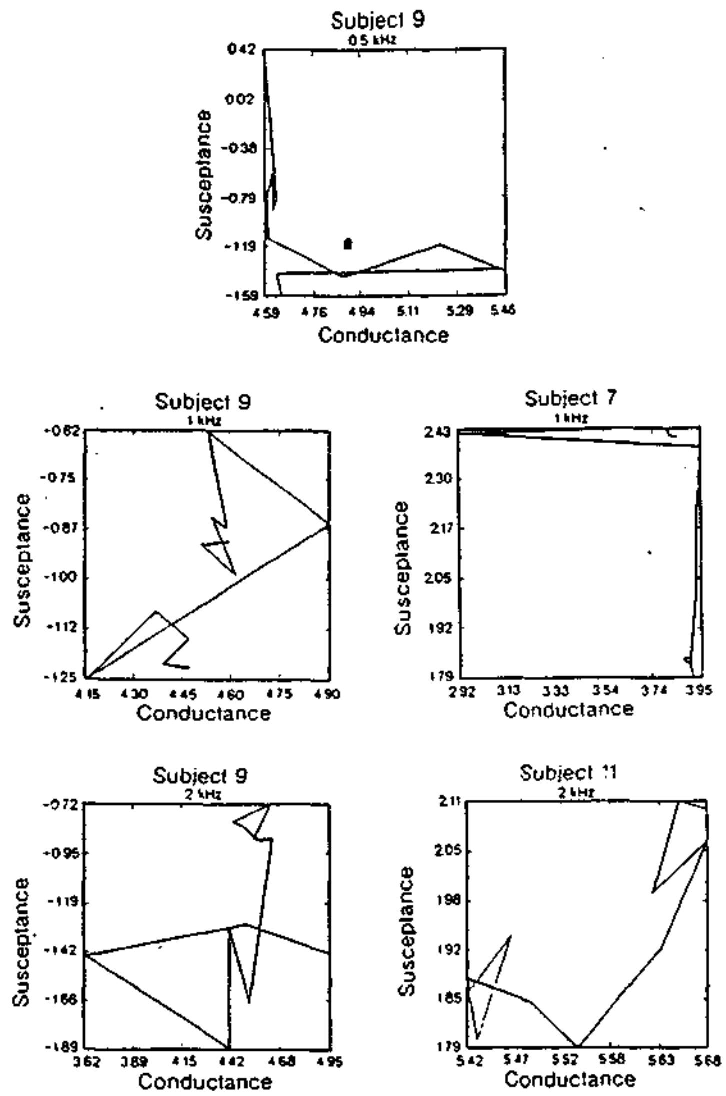


fig V (6):Examples of phasors which are approximately circular in shape but do not show an increase in stiffness

models of the middle ear function. The phasor diagram approach for high-probe-frequency measures suggest that the effect of the reflex is to add stiffness and not alter resistance significantly in most ears where the probe frequency is below or close to the resonance frequency of the middle ear.

HIGH FREQUENCY AUDITORY BRAINSTEM RESPONSE AUDIOMETRY

A few recent studies on high-frequency auditory brainstem - response audiometry are as follows:

Fausti, , Frey, Henry, Olson, (1992) conducted a study to evaluate auditory brain-stem responses (ABRs) obtained with the portable high-frequency tone-burst system (PARVA - PTB) as compared to the laboratory system (PARVA - TB). To determine the validity of these responses, latencies measured on both systems were compared with all other variables held constant (study - 1). To determine response reliability, intersession latency differences between two groups evaluated independently on each system were compared (study - 2). 35 nomal hearing subjects were evaluated in these two studies. Study 1 contained five subjects, (four females and one male), aged 19-27 years. Study 2 comprised 30 subjects, (13 males and 17 females) aged 16-32 years. Puretones of air- conduction at conventional- frequencies were obtained with a Grason-Stadler 1701 clinical audiometer for study (1). Hearing in high-frequency range was assessed using the laboratory high-frequency audiometer (PARVA - High-frequency (PARVA - HF); Fausti et al 1979, 1990). For study 2, both conventional-frequency and high-frequency thresholds were assessed with a Virtual model 320 audiometer. Aural immitance screening was conducted with a Virtual 310 immitance meter.

PARVA - TB (laboratory toneburst system):

This system was described by Fausti et al (1991 a,b). It is composed of rackmounted equipment, including a Gen Rad 1312 oscillator to generate the puretone signal; modular analog logic components (Grason-Stadler 1200 series) to control rise fall time, duration, rate and attenuation, and a filter - amplifier (Fausti, 1979) constructed to provide high quality puretone stimuli. The active filter amplifier net- work was inserted to match KOSS HV/IA earphone input impedance, improve the signal-to-noise ratio, lower the side bands and narrow the bandwidth. The stimulus generating system was coupled to the external trigger input of a Nicolet 170 evoked potential signal averager.

PARVA - PTB (portable tone-burst system):

The high-frequency tone-brust stimulus - generating unit is described by Fausti et al. Briefly, this light - weight (<51b) unit is constructed of both analog and digital circuits in order to maximize the benefits of both of these signal-processing methods. Digital circuits allow for programmable output function in the time and amplitude domains, while analog circuits provide the quality high - frequency stimuli which currently cannot easily be obtained with digital components. The stimulus output from any signal average capable of generating a 4.8 volt square - wave (click) stimulus acts as a trigger source for this external stimulus generator. The Biologic-Traveler signal average was selected because of its portability (451b).

In the study mentioned above, the authors have used tone burst centered at frequencies of 8, 10, 12 and 14 KHz which were gated with risefall times of 0.2 ms . The duration between zero voltage points was 2.0 ms. The results of this investigation demonstrated that the PARVA - TB laboratory evaluation system and the PARVA - PTB portable stimulus generator were comparable in their abilities to measure ABRs to high frequency tone bursts stimuli. Repeated measurements within subjects demonstrated PARVA - PTB reliability consistent with test-retest differences observed in previous high-frequency tone-burst reliability studies utilizing the PARVA - TB. It was determined, therefore, that the PARVA - PTB can be used as a realible effective high-frequency auditory monitoring tool, especially in the case of unresponsive patients receiving potentially ototoxic agents who are unable to be transported to laboratory for testing.

Fausti, Ol son, Frey, Henry, Schaffer, (1993) determined the relationship between response latency and intensity of stimulation in normal- hearing individuals for high-frequency tone-burst evoked ABRs. In this study 14 individuals (nine males and five females) of age range 16-32 (mean age 22 years) were evaluated. A Biologic Traveller evoked potential signal averager was used to generate click stimuli through Telephonic, TDH-39 P earphones.High-frequency toneburst stimuli at 10,12 and 14 kHz were presented by a portable signal generator described by Fausti et al through the modified Pro/4x plus earphones. This stimulus generator provides six attenuation steps from maximum output to - 60 dB in 10 dB increment. Additional attenuation of high-frequency tone burst stimuli, required for acquisition of behavioural and objective ABR thresholds, was accomplished with a Hewlett -Packard (H-P) 350 D attenuator. A two-channel differential electrode montage was utilized:

Placement of electrodes : Forehead (ground)
Vertex (non inverting)
Right mastoid (inverting, channel 1)
Left mastoid (inverting, channel 2)

High-frequency tone burst stimuli for all subjects were presented at four intensity levels from 100 down to 70 dB pe SPL. ABR threshold was defined as the lowest intensity at which wave V could be measured. Behavioral threshold of ABR stimuli was defined as the lowest intensity at which a subjective response could be obtained.

The results of this study are as follows:

(Since wave III was absent in many responses and / or highly variable, the wave III data was excluded from further analysis).

- No significant intra - or intersession differences were detected for waves I and wave V for tone bursts ($P>0.05$) -For each tone burst frequency, there was significant, differences in mean latencies between intensity level ($P<0.05$) (Table VI (1)). Latency intensity functions (LIF) for wave I and V for all tone bursts can be seen in Fig. VI (1)

Table VI (1) : Mean latencies and differences for 14 subjects for all stimulus conditions at four intensity level

dB peSPL	Wave 1			
	8kHz	10 kHz	12 kHz	14 kHz
	Lat (Diff)	Lat (Diff)	Lat (Diff)	Lat (Diff)
100	2.04 (0.22)	2.01 (0.19)	2.04(0.19)	2.24 (0.21)
90	2.26 (0.34)	2.20 (0.39)	2.23	2.45 (0.19) .
80	2.60 (0.25)	2.59 (0.12)	2.47(0.19)	2.64 (0.21)
70	2.85	2.71		

dB peSPL	Wave 1			
	8kHz	10 kHz	12 kHz	14 kHz
	Lat (Diff)	Lat (Diff)	Lat (Diff)	Lat (Diff)
100	6.51 (0.26)	6.60 (0.33)	6.86 (0.19)	7.05 (0.25)
90	6.82 (0.25)	6.93 (0.33)	7.05 (0.16)	7.30(0.19)
80	7.07 (0.19)	7.25 (0.23)	7.22 (0.27)	7.49 (0.32)
70	7.26	7.49	7.49	7.81

- Wave V was generally observed at low intensities, but wave I was not.
- Wave I slope functions for all t one bursts, calculated by linear regression analysis for each frequency, ranged from 0.020 to 0.027 in msec/dB. For wave V, the slope functions ranged from 0.020 to 0.030 msec/dB.
- ABR thresholds to tone bursts at 8, 10, 12 and 14 kHz averaged 15 dB higher than behavioral thresholds to these stimuli.
- Latencies shift out with decreases in intensity and due to sensitivity differences between 8 and 14 kHz, the ABR was detectable at 50 dB pe SPL for 8 kHz, but not for 14 kHz, Fig. VI (2).

The authors of this study discusses about the findings as follows:

- ABR intra and intersession reliability to high frequency tone burst stimuli was found to be comparable to results of a response reliability study which used identical stimuli (Fausti et al 1991 b).
- Wave III is the least sensitive for responses to clicks and conventional tone bursts. This is true in cases for high-frequency tone-burst also.
- Wave I and V both revealed consistent LIFs to high-frequency tone-burst. Wave V was generally more robust and thus easier to score, allowing peak latency measurement closer to threshold. Wave I responses were seen to deteriorate below 70 dB pe SPL, while wave V peaks were observed down to 50 dB pe SPL. As intensity decreases, responses are weakened and wave I becomes indistinguishable from the physiological noise floor sooner than wave V.
- Tone burst at 8, 10, 12 and 14 kHz evoked responses that decreased in latency as a function of increasing intensity.
- The smaller slope functions obtained with the high-frequency tone-burst ABRs in comparison to low-frequency and click evoked ABRs may be due to high-frequency excitation being restricted to a narrow area in the cochlea or having a narrow traveling wave envelope campared to low frequencies (Moller, 1981).
- It has been shown that LIFs exists for waves I and V in response to with high-frequency tone-bursts in the 8-14 kHz range, and that these functions are consistent and orderly.

Each 10 dB shift in intensity resulted in mean latency differences between the stimulus intensities. Since most of these latency shifts were statistically significant, a like shift in a patient receiving ototoxic drug may be considered suggestive of a decrease in hearing.

Fausti, Olson, Frey, Henry, Schaffer, Phillips, (1995) determined how sensorineural hearing loss might affect ABRs to high-frequency tone-bursts. They conducted the study for the purpose of obtaining latency-intensity functions and test repeatability in response to tone bursts at frequencies 8, 10, 12 and 14 KHz in individuals having confirmed sensorineural hearing loss. 20 subjects with confirmed 'moderate' high-frequency sensorineural hearing loss were taken for the study. A portable evoked potential signal averager was used to generate click stimuli, presented through TDH - 39 P earphones. High-frequency tone-burst stimuli at 8,10,12 and 14 KHz were presented by a portable signal generator described by Fausti et al (1991a) through a modified Pro/4X plus earphone.

The results showed sufficient wave V response data for 8,10 and 12 kHz tonebursts. Intensity ranges yielding adequately analysable data for LIFs of wave V were 40-120 dB pe SPL for clicks and 70-120 dB pe SPL for 8, and 10 kHz tonebursts. Resulting ABR waves I and III were less prevalent and could not be subjected to detailed statistical analysis. Mean latencies for clicks and tone bursts (8 and 10 KHz) are shown in Table VI (2) at each presentation level.

Table VT(2): Wave V mean latencies (in mses) demonstarting LIFs for the 20 subjects for the click and high frequency (8 and 10 kHz) toneburst conditions at 40-120 dB peSPL and 70-120 db peSPL intensity levels respectively.

dB peSPL	Click	8kHz	10 kHZ
120	5.76	6.67	6.79
110	5.97	6.68	6.85
100	6.19	6.97	7.35
90	6.41	7.20	7.32
80	6.74	7.52	7.81
70	6.58	7.70	7.88
60	6.99	-	-
50	7.74	-	-
40	8.07	-	-

With each 10 dB increase in stimulus level, mean latencies decreased an average of 0.29 msec for clicks and 0.21 msec for 8 kHz tone burst and 0.22 msec for 10 kHz tonebursts. Latency-intensity functions (LIFs) for clicks and for 8 and 10 kHz toneburst are displayed in Fig. VI (3). Although too few responses were obtained at 12 and 14 kHz to allow LIF analysis, this same latency - intensity trend was apparent. Comparisons were made between the current subjects and a group of normal hearing subhects reported in Fausti et al 1993 (b).

Table VI(3): Wave V mean latencies (in mses) comparing fourtenn normal hearing and twenty sensory neural hearing impaired individuals for the high frequency (8 and 10 kHz) toneburst conditions at 40-120 dB peSPL and 70-120 db peSPL intensity levels respectively.

	8kHz		10khz	
pcSPL	Normal	Scnsorincural	Normal	Scnsorincural
100	6.51	6.97	6.60	7.35
90	6.82	7.20	6.93	7.32
80	7.07	7.52	7.25	7.81
70	7.26	7.70	7.49	7.88

Table VI (3) shows wave V mean latencies for 8 and 10 kHz tone bursts per l0dB intensity level shift for fourteen normal hearing and twenty sensori neural hearing impaired subjects. At each presentation level, mean latencies were longer for the sensorineural hearing impaired group (ranging from 0.38 to 0.75 msec later). The linear regression curves showed no significant differences between normal hearing subject group and this sensorineural hearing-impaired group showed no significant difference. As frequency increased, the number of wave V responses decreased across subject sample. Wave V responses to 8 and 10 kHz toneburst revealed orderly decreases in latency as a function of increasing intensity. The latencies were generally longer for the hearing impaired group. Linear regression showed that the slopes between groups of 8,10 and 12 kHz were essentially parallel and not significantly different from each other. (Fig. VI (4). Thus the main effect of the hearing loss appears to be peak latencies that are longer by about the same amount at all intensity levels. At the same dB pe SPL presentation levels of clicks and tone-bursts, waveforms were less

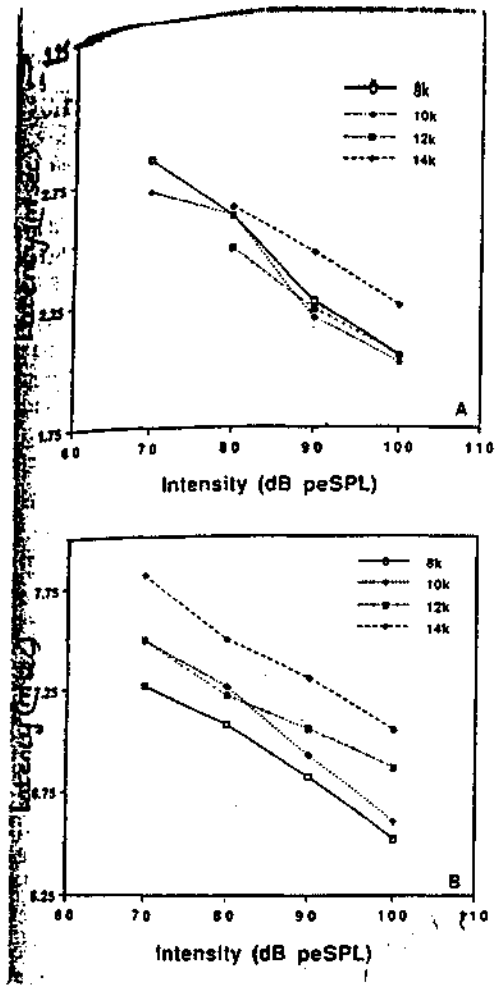


Fig VI (1) IA:subject wave I latency-intensity functions vill high-frequency (8, 10. 12, and 14 kHz) tone burst auli in the intensity range of 100-70 dB peSPL. B. fcrteen subject wave V latency-intensity functions for all frequency (8. 10. 12. and 14 kHz) tone burst stimuli in Hntensity range of 100-70 dB pcSPL.

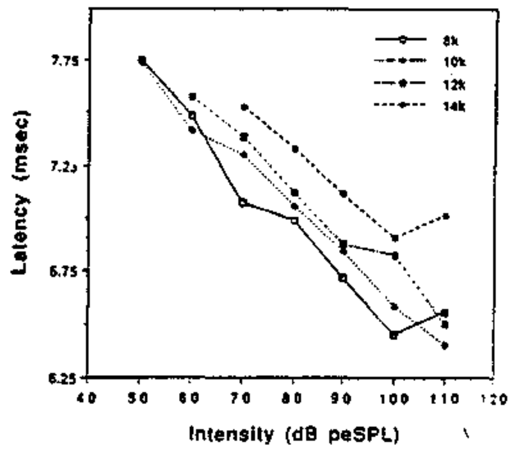


Fig VI (3): subject subgroup wave V la'tency-intensity functions for all high-frequency (8. 10. 12, and 14 kHz) use burst stimuli in the intensity range of 110-50 dB peSPL

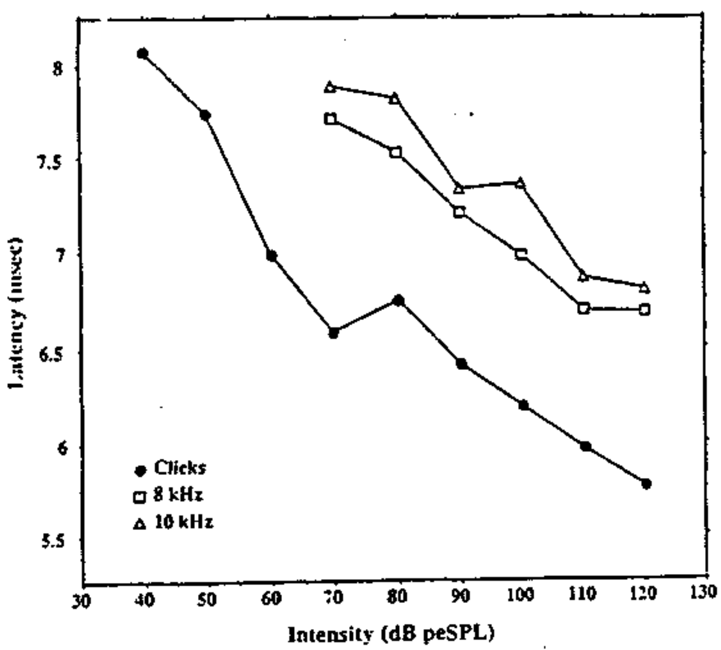


Fig VI (2): Latency-intensity functions from clicks and high-frequency (8 and 10 kHz) toneburst stimuli in subjects with known cochlear damage.

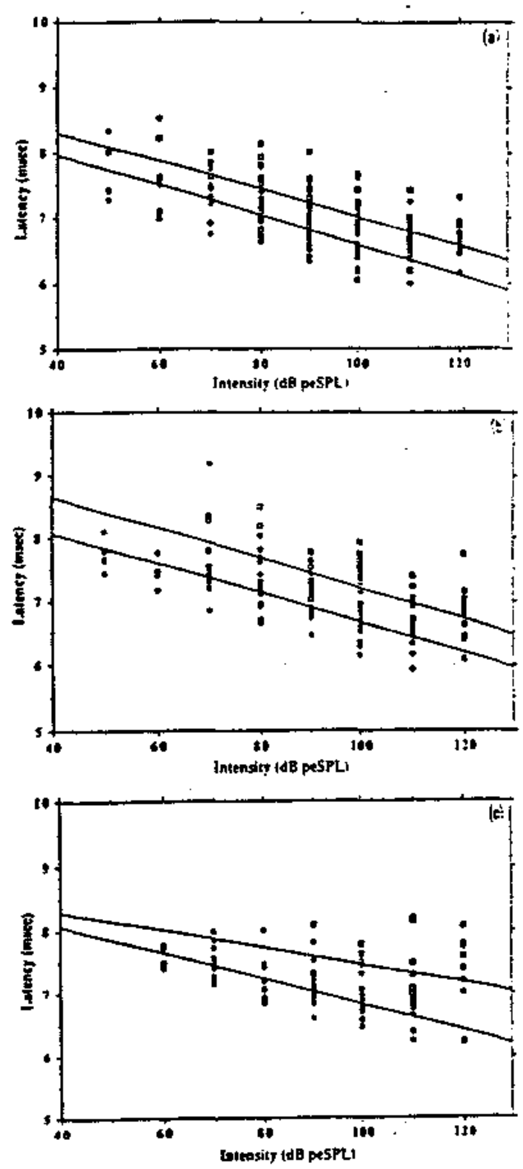


Fig VI (4): Wave V linear regression linss from all a^ailabie datapoints from 14 normally hearing and 20 sensorineurji hearing-impaired individuals for (a) 8. iM 10. and (c) 12 kHz toneburst stimuli.

well defined and latencies longer for tone bursts than for clicks. Spectral characteristics of clicks stimulated frequency regions of better hearing sensitivity in these sensorineural hearing-impaired subjects. Comparatively characterstics of the high-frequency-specific toneburst, stimulated regions of poorer hearing sensitivity. Thus sensation level (SL) differences between clicks and toneburst could account for much, if not all, of the differences in waveform definition. Sensation levels were considerably higher for clicks than for toneburst and click latencies would be expected to be correspondingly shorter. Also as tonebursts increased in frequency, sensation levels were reduced with consequent increases in latency. This study demonstrated that this high-frequency toneburst ABR technique shows definite promise as an early indicator of hearing change prior to the conventional frequency test methods.

SUMMARY AND CONCLUSION

The above chapters dealt with the development in the area of High-frequency audiometer from the year 1988 to 1998. From the various articles reviewed for these ten years, the following conclusions were obtained which is briefly outlined here.

- Age related changes are found in high-frequency sensitivity and the high-frequency sensitivity decrease with age.

- There are no significant difference in high-frequency hearing between ears (right ear and left ear).

- Gender differences for high-frequency hearing sensitivity was not significant.

- High-frequency electric-bone-conduction thresholds can be measured monaurally if the contralateral ear is masked with air conduction signals and the minimum masking level was 50-60 dB SPL in the high-frequency range.

- Effectiveness of contralateral masking to eliminate cross hearing in investigations of high-frequency bone conduction thresholds measurements were studied

- High-frequency audiometry has various clinical implication. Studies revealed a relationship between high-frequency sensitivity and otitis media, ototoxicity, noise induced hearing loss, tinnitus, obscure auditory dysfunction etc.

- High-frequency ABR techniques also show a definite indication of hearing change prior to the conventional frequency test methods.

Most of the studies showed that high-frequency audiometry is a good diagnostic tool for hearing assessment.

APPENDIX

HIGH FREQUENCY AUDIOMETER USED AT
ALL INDIA INSTITUTE OF SPEECH AND HEARING, MYSORE

- GSI 61 Clinical Audiometer is the audiometer used at AIISH, which also has the option for measuring high frequencies (8 to 20kHz). GSI 61 is a registered trademark of Grason- Stadler Inc.

This audiometer meets or exceeds the following standards; ANSI S3.6 - 1989; ANSI S3.43-1992; IEC 645-1 (1992); IEC 645-2 (1993); ISO 389; UL 544 Listed Hospital and Dental equipment; IEC 601-1 Medical Electrical Equipment and CSA C22.2, No. 601-1-M90 Electromedical equipment.

This audiometer has the following facilities.

- Pure tone-Channel 1 and channel 2:

Frequency range:- Air-conduction 125Hz to 12000Hz,

:- High-frequency (optional) 8kHz to 20 kHz.

:- Bone-conduction 250 to 8000Hz

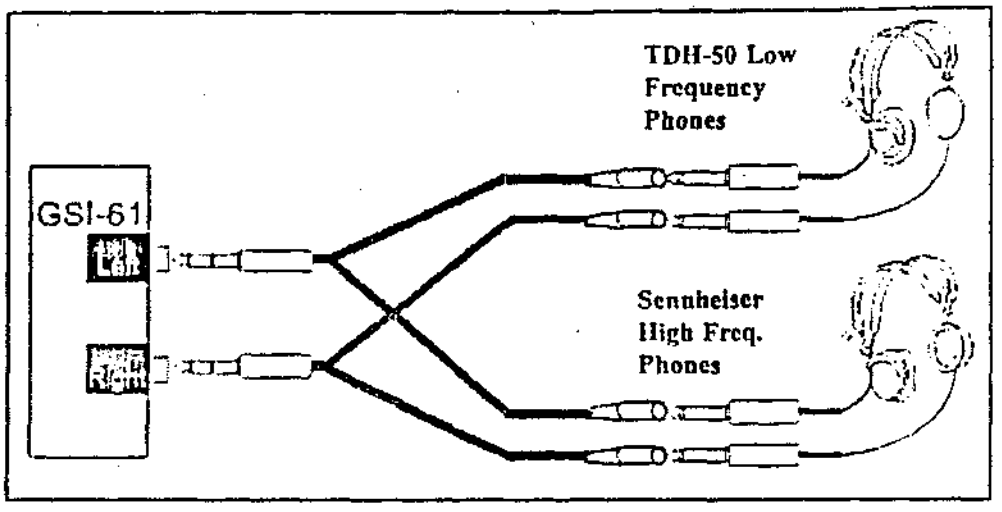
:- Sound field (optional) 125Hz to 12000Hz (125 Hz to 16,000 Hz only with high-frequency option).

Intensity range :- Air conduction -10 dBHL to 120 dBHL,

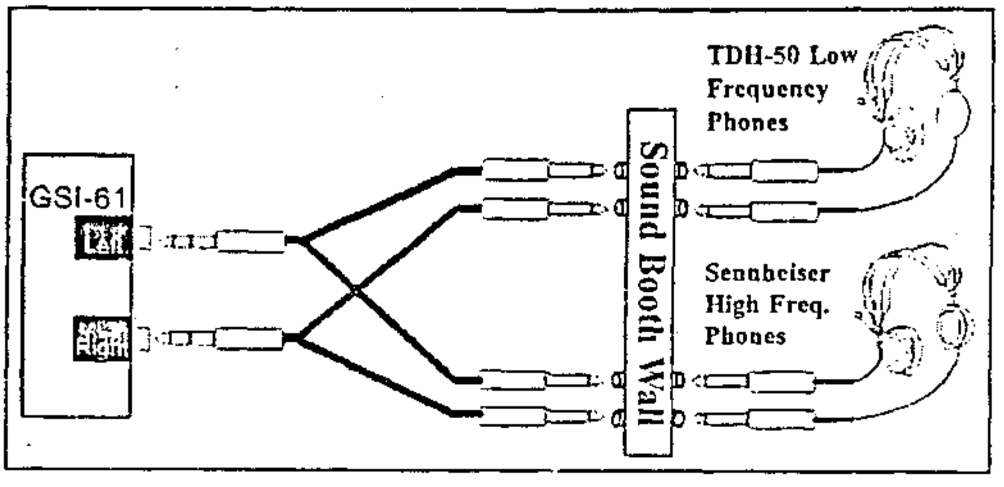
:- high-frequencies -20dBHL to lOOdBHL (with Sennheiser HDA 200 earphone).

Tone testing in the frequency range of 8kHz to 20kHz using high-frequency phones or sound field. The frequencies available for testing are: 8kHz, 9kHz, 10kHz, 11.2kHz, 12.5kHz, 16kHz, 18kHz, and 20kHz (optional). The other optional accessories are high-frequency headphones with booth cables, high-frequency cables to sound booth, high-frequency headphones, with cables to GSI 61 and high-frequency cables. The high-frequency earphones are connected to stereo cable extensions which in turn are connected into the right and left phone jacks on the rear pannel. When the high-frequency option is installed, connect the standard TDH 50P earphone cords into the stereo cable extensions labeled 'Std'. The following two figures show the installation of the high-frequency and TDH 50P earphones. When the Sennheiser high-frequency phones are used and the high-frequency option is enabled, the frequencies available for testing are 8kHz, 9kHz, 10kHz, 11.2kHz, 12.5kHz, 16kHz, 18kHz, and 20kHz (optional). The intensity range is from - 20dB to 110dBHL. High-frequency audiometery can also be performed in sound field using the Basic Speakers configuration. In high-frequency sound field, the frequencies of 8kHz, 9kHz, 10kHz, 11.2kHz, 12.5kHz, 16kHz, (optional).

The test frequency buttons will roll over to the lowest frequency after the last valid frequency or the frequency will automatically go to the nearest valid value when a different transducer is selected.



High Frequency Option Setup: No Sound Booth



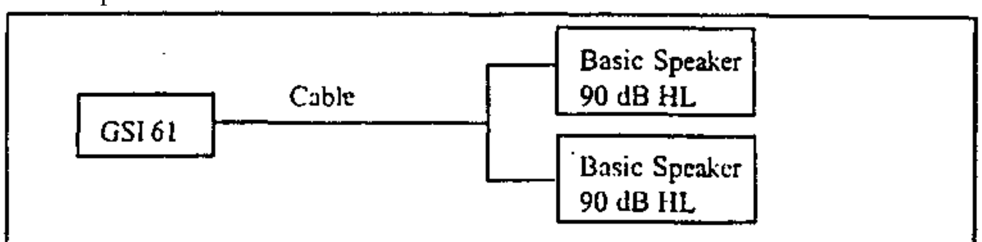
High Frequency Option Setup: With Sound Booth

dBHL limits per frequency in the high frequency range

	SOUND FIELD 45° AZIM UTH	HIGH FREQUENCY EAR PHONE
8000	80	100
9000	80	100
10000	80	95
11200	80	95
12500	80	84
14000	75	75
16000	50	55
18000	N/A	35
20000	N/A	14

High frequencies with sound field can only be selected with the Basic Speakers.

Note that the High Frequency with Sound Field can only he selected with the Basic Speakers.



Sound Field System 90 dB HL - Basic Speakers and Cable
Frequency Range: 125 to 16,000 Hz

Band width for Narrow Band Masking sounds for high frequency (Pass band upper and lower frequency limits at 3dB points).

CENTER FREQUENCY Hz	LOWER FREQUENCY Hz	UPPER LIMITS Hz
8000	6730-7130	8980-9510
9000	7570-8020	10100-10700
10000	8410-8910	11220-11890
11200	9420-9980	12570-13320
12500	10510-11140	14030-14870
14000	11770-12470	15710-16650
16000	13450-14250	17960-19030
18000	15138-16042	20196-21413
20000	16820-17812	22440-23792

Speaker reference thresholds levels Re: 20 Pa.

FREQUENCY Hz	45° AZIMUTH	O° AZIMUTH
8000	8.0	13.5
9000	10.5	15.5
10000	11.0	15.5
11200	10.0	14.0
12500	11.5	13.0
14000	16.0	18.0
16000	43.5	44.5

- Forty five degree Azimuth reference thresholds values are based on ISO 8253-2.

- Zero degree azimuth reference threshold values are based on ISO 226-1.

Reference levels for pure tones wit Sennheiser HDA 200

SPL values with the Sennheiser HDA ear phones for 0 dBHL setting.

FREQUENCY Hz	SENNHEISER HDA 200
8k	16.0
9k	17.0
10k	21.5
11.2k	21.0
12.5k	27.5
14k	37.5
16k	58.0
18k	83.0
20k	105.0

Reference threshold values based on ISO/TC 43/WG IN 190 and Tom Frank, Ph.D: "High frequency hearing thresholds in young adults using a commercially available audiometer", ear and Hearing Vol. 11 No.6,1990.

Calibration of GSI 61

The calibration mode may be entered directly from power up or from the Normal Mode. The calibration entry switch is slide switch which is accessible at the rear panel of the unit. The calibration mode option Dip switches are read upon entry to the calibration mode.

To enter the calibration mode: set the Dip switches to the appropriate settings, ensure the Cal/Diag Mode Dip switch (S901-1) is in the Cal position (OFF) and then move the CAL/NORMAL (S1000) slide switch to the CAL position. The channels must be OFF to enter the calibration mode. The Dip switch for the high-frequency phone type is S901-6.

Enter the calibration mode and connect the selected transducer to the sound level meter using the selected coupler. If the speakers are being calibrated, position the sound level meter microphone at the expected patient head position, using the selected speaker azimuth. This must be no longer than one meter from the speaker cones to ensure the minimum published GSI maximum HL limits. Select the appropriate CH1 routing transducer combination, stimulus/ frequency, signal format and step size. Adjust the Reference HL level (CH2 HL Dial and Display) at which the calibration will be performed, and turn on the stimulus (CH1 Tone Bar). Adjust the attenuator (CH1 HL Dial) until the sound level meter reads the Target SPL value displayed in the CH1 Intensity field and store the data into EEPROM by pressing the DATA transfer or save keys. This procedure is repeated unit every transducer / routing combination and stimulus is calibrated.

The position of the phone coupler dip switch does not apply to high-frequency phones. The coupler type for high frequency is always set to IEC 318 with FP" as this is the only coupler recognized by the international standards.

High-frequency cannot be entered without either the high-frequency Y-cords plugged into earphones jacks or no cables plugged into jacks. In Cal mode the "High-frequency" key must be selected to calibrate frequencies above 12kHz.

BIBLIOGRAPHY

1. Aguilar - Markulis,N.V., Beckley, S., Priore, A, (1981). Cited in Dreschler, W.A., Van der Hulst, R.J.A.M., Tange, R.A., Urbanus. NAM (1989). Role of High Frequency Audiometry in the Early Detection of Toxicty. II Clinical Aspects. Audiology, 28 (4), 211-220.

2. Arnold, W., Ganzer, U., Kleinmann, H. (1977). Cited in Margolis. R.H., Hunter, L.L., Rykken, J.R., Giebink, S.G, (1993). Effects of Otitis Media on Extended High-Frequency Hearing in Children. Annals of Otology, Rhinology and Laryngology, 102. 1-5.

3. Berlin, C.I. (1982). Cited in P.A. Yantis. (1994). Puretone Air-Conduction Threshold Testing. In J. Katz, (Ed.). Handbook of Clinical Audiology. 4th edn., pp 97-108. Baltimore, Williams and Wilkins.

4. Barnea, G., Attias, J., Gold, S., Shahor, A. (1990). Tinnitus with Normal Hearing Sensitivity : Extended High-Frequency Audiometry and Auditory Nerve Brain-Stem-Evoked Responses. Audiology.29(6), 36-45.

5. Barron, SE., Diagneault, E.A. (1987). Cited in Fausti. S.A., Henry. J.A.. Schaffer, H.I., Olson, D.J., Frey, R.H., Bagby, G.C. (1993). High Frequency Monitoring for Early Detection of Cisplatin Ototoxicity. Archives of Otolaryngology Head Neck Surgery, 119, 661-666.

6. Bednin, F.V., Sagalovich, B.M. (1976). Cited in Silman, S. and Silverman, C.A. (1991). Auditory diagnosis. Principles and Applications, pp 10-70, California : Academic Press, Inc.

7. Beiter, R.C., Talley, J.N. (1976). Cited in P.A. Yantis, (1994). Puretone Air-Conduction Threshold Testing. In J.Katz, (Ed.). Handbook of Clinical Audiology. 4th Edn, pp. 97-108. Baltimore : Williams and Wilkins.

8. Beiter, R.C., Rupp, R.R. (1972). Cited in P.A. Yantis, (1994). Puretone Air-Conduction Threshold Testing. In J. Katz, (Ed.). Handbook of Clinical Audiology. 4th Edn. pp 97-108. Baltimore : Williams and Wilkins.

9. Berlin, C, Wexler, K.F., Jerger, J.F., Haperlin, M.R. and Smith, S. (1978). Cited in Filipo, R., De Seta, E. and Bertoli, G.A. (1988). High-Frequency Audiometry in Children. Scandinavian Audiology. 17,213-216.

10. Berlin, C.I. (1982). Cited in Silman,S., Silverman, C.A., (1991); Auditory Diagnosis : Principles and applications, pp 10-70. Califormia : Academic Press. Inc.

11. Buhrer, C, Weinel, P., Sauter, S., Reiter, A., Reiter, R., Reihm, H. (1990). Cited in Fausti, S.A., Henry, J.A., Schaffer. H.I., Olson, D.J., Frey, R.H., Bagby, G.C. (1993). High Frequency Monitoring for Early Detection of Cisplatin Ototoxicity. Archives of Otolaryngology Head Neck surgery, 119, 661-666.

12. Bredberg, G. (1967). Cited in Trehub, S.E., Schneider, B.A.. Morrongiello, B.A., Thorpe, L.A., (1989). Developmental Changes in High Frequency Sensitivity. Audiology, 28, 241-249.

13. Corliss, L.M., Doster, M.E., Simonton, J., Downs, M. (1970). Cited in Hallmo, P., Borchegrevink, H.M., Mair, I.W.S. (1995) Extended High Frequency Thresholds in Noise Induced Hearing Loss. Scandinavian Audiology, 24, 47-52.

14. Corso, J.F. (1964) cited in Silman. S., Silverman, C.A. (1991) Auditory diagnosis : Principles and Applications : pp 10-70. California : Academic Press, Inc.

15. Cunningham, D.R., Goetzinger, C.P. (1974). Cited in Filipo, R., De Seta, E., Bertoli, G.A. (1988). High-Frequency Audiometry in Children. Scandinavian Audiology, 17,213-216.

16. Cunningham, D.R., Vise, L.K. and Jones, L.A. (1983). Cited in Filipo. R., De Seta, E., Bertoli, G.A. (1988). High-Frequency Audiometry in Children. Scandinavian Audiology, 17. 213-216.

17. Cusimano, F., Cocita V.C., D'Amico (1989). Cited in Margolis R.H.. Hunter L.L., Rykken, J.R., Giebink. S.G. (1993). Effects of Otitis Media on Extended High Frequency Hearing in Children. Annals of Otology, Rhinology and Laryngology, 103, 1-5.

18. Decraemer, W.J., Khanna, S.M., Funnell,W.R.J. (1989). Cited in Mair, I.W.S., Hallmo, P (1994). Myringoplasty : a Conventional and Extended High-Frequency Air and Bone Conduction Audiometric Study. Scandinavian Audiology. 23 (3) 205-208.

19. Decraemer, W.R, Khanna, S.M., Funnell, W.R.J., (1991). Cited in Mair, I.W.S., Hallmo, P (1994). Myringoplasty : A Conventional and Extended High-Frequency Air and Bone Conduction Audiometric Study. Scandinavian Audiology. 23 (3) 205-208.

20. Dieroff, H.G. (1982). Cited in Filipo, R., De Seta, E. and Bertoli, G.A. (1988). High-Frequency Audiometry in Children. Scandinavian Audiology, 17,213-216.

21. Dirks, D., Malmquist, C. (1964). Cited in Lopponer, H. High-Frequency Audiometry : Masking in Electric Bone Conduction Audiometry, Scandinavian Audiology, 21, 31-35.

22. Domenech, J., Carulla, M., Traserra, J. (1989). Citied in Hallmo. P.. Mair, I.W.S. (1996). Drilling in Ear Surgery- A Comparison of Pre- and Post-Operative Bone-Conduction Thresholds in Both the Conventional and Extended High Frequency Ranges. Scandinavian Audiology, 25, 35-38.

23. Domenech, J., Cuchi, M.A., Fuste, J., Traserra - Coderch, J. (1993). Evaluation of the Possible Ototoxicity of Josamycis by High Frequency Audiometry. An Otorrinolaringol - Ibero- Am . 20(2). 173-178 Cited in Scientific Update and Newscan Sun Pharamceutical Industries Limited. Gujarat, India.

24. Dommerby, H., Tos, M. (1986). Cited in Margolis, R.H. Hunter., L.L., Rykken. J.R., Grebink, S.G (1993). Effects of Otitis Media on Extended High-Frequency Hearing in Children. Annals of Otology, Rhinology and Laryngology, 102,1-5.

25. Dreschler, VA., Hulst, R.J.A.M v.d., Tange, R.A., Urbanus, N.A.M. (1985). Cited in Trehub, S.E., Schneider, B.A., Morrongiello, B.A., Thorpe, L.A., (1989). Developmental Changes in High Frequency Sensitivity. Audiology, 28, 241-249.

26. Dreschler, W., Vander Hulst, R.J.A.M., Tange, R.A., Urbanus, N.A.M. (1989). Role of High Frequency Audiometry in the Early Detection of Otrotoxicity. Audiology, 28(4), 211 -220.

27. Dreschler, W.A., Vander Hulst, R.J.A.M. (1987). Cited in Stelmachowicz, P.G., Beauchaine, K.A., Kalberer, A., Jesteadt. W. (1989). Normative Thresholds in the 8 to 20 kHz Range as a Fuction of Age. Journal of Acoustical Society of America, 86(4), 1384-1391.

28. Dreschler., W.A., Vander Hulst, R.J., Tange, R.A., and Urbanus, N.A. (1985). Cited in L.A. Wilber. (1991). Puretone Audiometry : Air and Bone-Conduction. Rintelmann, W.F. (Ed.). Hearing Assessment. 2nd Edn. pp. 1-38. Massachusetts, Allyn and Bacon, A Division of Simon and Schuster, Inc.

29. Erickson, D.A., Fausti, S.A., Frey, R.H., Rappaport, B.Z. (1980). Cited in Trehub, S.E., Schneider, B.A., Morraongiello, B.Z., Thorpe. L.A. (1989). Developmental Changes in High Frequency Sensitivity. Audiology, 28, 241-249.

30. Fausti, S.A., Gray, P.S., Frey, R.H., Mitchell, C.R. (1991(a)). Cited in Fausti, S.A., Olson, D.J., Frey, R.H., Henry, J.A., Schaffer, H.I., Phillips, D.S. (1995). High Frequency Tone Burst - Evoked ABR Latency — Intensity Functions. Scandianavian Audiology, 22, 25-33.

31. Fausti, S.A., Frey R.H., Erickson, D.A., Rappaport, B.Z., Cleary, E.J. (1979). Cited in Dreschler, W.A., Van der Hulst, R.J.A.M., Urbanus, N.A.M (1988). High Frequency Audiometery in Prospective Clinical Research of Ototoxicity Due to Platinum Derivatives. Annals of Otology, Rhinology and Laryngology, 97, 133-137.

32. Fausti, S.A., Frey, R.H., Erickson, D.A., Rappaport, B.Z., Cleary, E.J. (1979). Cited in Dreschler, W.A., Van der, R.J.A.M., Urbanus. N.A.M. (1988). High Frequency Audiometry in Prospective Clinical Research of Ototoxicity due to Platinum Derivatives. Annal of Otology, Rhinology and Laryngology, 97, 133-137.

33. Fausti, S.A. Rappaport, B.Z., Frey, R.H., Henry, J.A., Phillips, D.S.. Mitchell, C.R., Olson, DJ. (1991b). Cited in Fausti. S.A., Olson, D.J.. Frey, R.H.. Henry, J.A., Schaffer, H.I., Phillips, D.S. (1995). High Frequency Tone Burst - Evoked ABR Latency - Intensity Functions in Sensorineural Hearing - Impaired Humans. Scandianavian Audiology. 22, 25-33.

34. Fausti,. S.A. Olson, D.J., Frey, R.H., Henry, J.A.. Schaffer, H.I. (1993 (b)). Cited in Fausti, S.A., Olson, D.J., Frey, R.H., Henry, J.A.. Schaffer, H.I., Phillips, D.S. (1995). High Frequency Tone Burst - Evoked ABR Latency - Intensity Functions in Sensorineural Hearing - Impaired Humans. Scandianavian Audiology, 24, 19-25.

35. Fausti, S.A., Gray P.S., Frey, R.H. Mitchell, C.R. (1991a). Cited in Fausti, S.A., Olson, D.J., Frey, R.H., Henry, J.A., Schaffer, H.I. (1993) High Frequency Tone Burst Evoked ABR Latency Intensity Functions. Scandinavian Audiology, 22(1), 25-33.

36. Fausti S.A., Rappaport, B.Z., Frey R.H., Henry, J.A., Phillips. D.S. Mitchell, C.R., Olson D.J. (1991b). Cited in Fausti S.A., Olson. D.J.. Frey. R.H., Henry J.A., Schaffers, H.I. (1993). High Frequency Tone Burst - Evoked ABR Latency - Intensity Functions. Scandinavian Audiology. 22(1), 25-33.

37. Fausti. S.A., Schechter, M.A., Rappaport, B.Z., Frey, R.H.. Mass. R.E. (1984). Cited in Fausti, S.A., Henry, J.A., Schaffer, H.I., Olson. D.J., Frey, R.H., Bagby, G.C. (1993). High Frequency Monitoring for Early Detection of Cisplatin Ototoxicity. Archives of Otolaryngology Head Neck Surgery, 119, 661-666.

38. Fausti, S.A., Frey, R.H.., Erickson, D.A., Rappaport. B.Z. (1979b). Cited in P.A. Yantis, (1994). Puretone Air-Conduction Threshold Testing. In. J. Katz. (Ed.). Handbook of Clinical Audiology. 4th Edn. pp. 97-108. Baltimore : Williams and Wilkins.

39. Fausti. S.A., Frey, R.H., Erickson, D.A., Rappaport. B.Z. (1979a) Cited in P.A. Yantis, (1994). Puretone Air-Conduction Threshold Testing. In J. Katz. (Ed.). Handbook of Clinical Audiology. 4th Edn. pp. 97-108. Baltimore: Williams and Wilkins.

40. Fausti, S.A., Frey, R.H., Henry, J.A., Olson, D.J., Schaffer, .H.I. (1992). Cited in Fausti, S.A., Olson, D.J., Frey, R.H.. Henry, J.A.. Schaffer, H.I., Phillips, D.S. (1995). High - Frequency Toneburst - Evoked ABR Latency - Intensity Functions in Sensorineural Hearing - Impaired Humans - Scandinavian Audiology, 24(1), 19-25.

41. Fausti, S.A., Frey, R.H., Henry, J.A., Robertson, P.G., Hertert R.S. (1992 b) Cited in Fausti, S.A., Olson, D.J., Frey, R.H., Henry, J.A.,

Schaffer, H.I., Phillips, D.S. (1995). High - Frequency Tone Burst Evoked ABR Latency- Intensity Functions in Sensorineural Hearing - Impaired Humans. Scandinavian Audiology, 24(1), 19-25.

42. Fausti, S.A., Frey, R.H., Herry, J.A., Robertson, P.G., Hertert R.S. (in press) Cited in Fausti, S.A., Olson, D.J., Frey, R.H., Henry, J.A.. Schaffer, H.I. (1993). High Frequency Tone Burst - Evoked ABR Latency - Intensity Functions. Scandinavian Audiology, 22(1), 25-33.

43. Fausti, S.A., Henry, J.A., Schaffer, H.I. Olson, D.J., Frey, R.H., Bagby, G.C. (1993 a). A High - Frequency Monitoring Protocol For Early Detection of Cisplatin Otoxity. Archives of Otolarngology Head Neck Surgery, 119, 661-668.

44. Fausti, S.A., Henry, J.A., Schaffer, H.I., Olson, D.J., Frey, R.H., Bagby, G.C. (1993 a) Cited in Fausti, S.A., Olson, D.J., Frey, R.H.. Henry, J.A., Schaffer, H.I., Phillips, D.S. (1995). High - Frequency Tone Burst - Evoked ABR Latency - Intensity Functions in Sensoineural Hearing - Impaired Humans. Scandinavian Audiology, 24(1), 19-25.

45. Fausti, S.A., Henry, J.A., Schaffer, HI; Olson, D.J., Frey, R.H., Mc Donald, W.J. (1992). High - Frequency Audiometric Monitoring for Early Detection of Aminoglycoside Ototoxicity. Journal of Infections Diseases, 165 (6), 1026 -1032. Cited in Scientific Update and Newscan. Sun Pharmaceutical Industries Limited. Gujarat, India.

46. Fausti, S.A., Olson, D.J., Frey, R.H, Henry, J.A., Schaffer, H.I. (1993 b) Cited in Fausti, S.A., Olson, D.J., Frey, R.H., Henry, J.A., Schaffer, H.I., Philips, D.S. (1995). High-Frequency Tone Burst Evoked ABR

Latency - Intensity Functions in Sensorineural Hearing-Impaired Humans. Scandinavian Audiology, 24(1), 19-25.

47. Fausti, S.A., Olson, D.J., Frey, R.H., Henry, J.A., Schaffer, H.I.. Phillips, D.S. (1995). High Frequency Toneburst-Evoked ABR Latency - Intensity Functions in Sensorineural Hearing-Impaired Humans. Scandianavian Audiology, 24(1), 19-25.

48. Fausti, S.A., Olson, D.J., Frey, R.H., Henry, J.A., Schaffer, H.I. (1993 b). High Frequency Tone Burst - Evoked ABR Latency. Intensity Functions. Scandinavian Audiology, 22, 25-33.

49. Fausti, S.A., Rappaport, B.Z., Schechter, M.A., Fry, R.H., Ward, T.T.. Brummett, R.E. (1984 a). Cited in Fausti, S.A., Olson, D.J., Frey. R.H., Herry, J.A., Schaffer, H.J. (1993). High Frequency Tone Burst - Evoked ABR Latency - Intensity Functions. Scandinavian Audiology. 22(1), 25-33.

50. Fausti, S.A., Rappaport, B.C. (1985). Cited in P.A. Yantis. (1994). Puretone Air-Conduction Threshold Testing. In J. Katz (Ed.). Handbook of Clinical Audiology. 4th edn. pp. 97-108. Baltimore : Williams and Wilkins.

51. Fausti, S.A., Rappaport, B.Z., Schechker, M.A., Frey, R.H. (1982). Cited in P.A. Yantirs. (1994). Puretone Air-Conduction Threshold Testing. In. J. Katz. (Ed.) Handbook of Clinical Audiology, 4th Edn. pp97-108. Baltimore : Williams and Wilkins.

52. Fausti, S.A., Schechter, M.A., Rappaport, B.Z., et al. (1984). Cited in Dreschler, W.A., Van der Hulst, R.J.A.M., Range, R.A., Urbanus,

N.A.M. (1989). Role of High Frequency Audiometry on the Early Detection of Ototoxicity. II Clinical Aspects. Audiology. 28(4). 211-220.

53. Fausti, S.A., Schechter, M.A., Rappaport, B.Z., Frey, R.H.. Mass, R.E. (1984b). Cited in Fausti, S.A., Olson, D.J., Frey, R.H., Henry, J.A., Schaffer, H.I. (1993). High-Frequency Tone Burst-Evoked ABR Latency - Intensity Functions. Scandinavian Audiology. 22 (1). 25-33.

54. Fausti, S.A., Schechter, M.A., Rappaport, B.Z., Frey, R.H.. Mass, R.E. (1984). Cited in Dreschler, W.A., Vander Hulst. R.J.A.M, Urbanus, N.A.M. (1988). High Frequency Audiometry in Prospective Clinical Research of Ototoxicity Due to Platinum Derivatives. Annals of Otology, Rhinology and Laryngology, 97, 133-137.

55. Faustic, S.A. Erickson, D.A., Frey, R.H., Rappaport, B..Z.. Schecter, M.A. (1981) Cited in Hallmo, P., Borchgrenivk, H.M., Main I.W.S. Extended High Frequency Thresholds in Noise Induced Hearing Loss. Scandinavian Audiology, 24, 47-52.

56. Fausti, S.A., Frey, R.H., Henry, J.A., Olson, D.J. (1992). Comparing Laboratory and Portable Tone - Burst Auditory Brain - Stem Response (ABR) Systems for Meonitoring High Frequency (>- 8KHz) Auditory Function. Scandinavian Audiology, 21,211 -217.

57. Fee, W.E. (1980) Cited in Fausti, S.A, Olson, D.J., Frey, R.H., Henry, J.A., Schaffer, H.I. (1993). High- Frequency Tone Burst-Evoked ABR Latency - Intensity Functions. Scandinavian Audiology, 22(1), 25-33.

58. Filipo, R., De Seta, C. (1983). cited in Filipo, R., De Seta, E., Bertoli. G.A. (1988). High-Frequency Audiometry in Children. Scandinavian Audiology, 17,213-216.

59. Filipo, R., De Seta., Bertoli, G.A. (1985). Cited in Filipo, R., De Seta. E. and Bertoli, G.A. (1988). High-frequency Audiometry in Children. Scandinavian Audiology, 17, 213-216.

60. Filipo, R., Deseta, E., Bertoli, G.A. (1988). High Frequency Audiometry in Children. Scandinavian Audiology, 17,213-216.

61. Fletcher, J.L. (1965) Cited in P.A.Yantis, (1994) Puretone Air-Conditions Threshold Testing. In J. Katz, (Ed.) Handbook of Clinical Audiology, 4th edn. pp. 97-108, Baltimore : Williams and Wilkins.

62. Flottorp.G. (1973). Cited in Trehub, S.E., Schnieder, B.A.. Morrongiello, B.A., Thorpe, L.A. (1989). Developmental Changes in High Frequency Sensitivity. Audiology, 28, 241-249.

63. Forastiere. A.A., Gennis ,M, Orringer, M.B., Agha, F.P. (1987). Cited in Fausti, S.A., Henry, J.A., Schaffer, H.I., Olson, D.J., Frey, R.H.. Bagby, G.C. (1993). High Frequency Monitoring for Early Detection of Cisplatin Ototoxicity. Archives of Otolaryngology Head Neck Surgery, 119,661-666.

64. Frank, T., and Ragland, A.E. (1987) Cited in L.A. Wilber, (1991). Puretone Audiometry : Air — and Bone — Conduction. In W.F. Rintelmann. (Ed.)- Hearing Assessment. 1-38. Massachusetts, Allyn and. Bacon, A Division of Simon and Schuster, Inc.

65. Frank, T., Dreisbach, L.E. (1991). Repeatability of High-Frequency Thresholds. Ear and Hearing, 12(4), 294-295.

66. Frank, T.. Ragland, A.E. (1987). Cited in Silman, S., Silverman, C.A. (1991). Auditory Diagnosis : Principles and Applications, pp. 10-70. California : Academic Press Inc.

67. Fritze, W., Kohlez, W. (1985) Cited in Hallmo, P., Borchgrevink, H.M., Mair, I.W.S. Extended High Frequency Thresholds in Noise Induced Hearing Loss. Scandinavian Audiology, 24, 47-52.

68. Funnell, W.R.J., Laszlo, C.A. (1982). Cited in Mair, I.W.S., Hallmo, P. (1994). Myringoplasty : A Conventional and Extended High Frequency Air and Bone Conduction Audiometric Study. Scandinavian Audiology, 23 (3), 205-208.

69. Gauz, M.T. Smith, M.M. (1987). Cited in L.A. Wilber. (1991). Puretone Audiometry : Air - and Bone - Conduction. In W.F. Rintelmann, (Eds). Hearing Assessment. 2nd Edn. pp. 1-38. Massachusetts, Allyn and Bacon, A Division of Simon and Schuster, Inc.

70. Gauz, M.T., Smith, M.M., Hinkle, R.R. (1986). Cited in L.A. Wilber. (1991). Puretone Audiometry, Air-and Bone-Conduction. In W.F. Rintelmann. (Ed.). Hearing Assessment. 2nd Edn. pp. 1-38. Massachusetts. Allyn and Bacon, A Division of Simon and Schuste, Inc.

71. Gijo, K., Aritomo, H., Goode, R.L. (1987). Cited in Mair, I.W.S., Fjermedal, O., Laukli, E. (1989). Air Conduction Thresholds and

Secretory Otitis Media : A Conventioanl and Extra-High Frequency Audiometric Comparison. Annals of Otalogy, Rhinology and Laryngology, 98, 767-771.

72. Goldstein, B., Shulman, A., and Kisiel, D. (1987) Cited in L.A. Wilber, (1991). Puretone Audiometry : Air - and Bone - Conduction. In W.F. Rintelmann. (Ed.). Hearing Assessment. 2nd Edn. pp. 1-38. Massachusetts, Allyn and Bacon, A Division of Simon and Schuster, Inc.

73. Gorga, M.P., Kaminski, J.R., Beauchaine, K.A. (1987). Cited in Fausti, S.A., Olson, D.S., Frey, R.H., Henry, J.A., Schaffer, H.I. (1993). High frequency Tone Burst - Evoked ABR Latency Intensity Functions. Scandinavian Audiology, 22(1), 25-33.

74. Green, D., Kidd, G., Jr., and Stevens, K. (1987). Cited in Stelmachowicz, P.G., Beauchaine, K.A., Kalberer, A., Jesteadt, W. (1989). Normative thresholds in the 8 to 20 kHz Range as a Function of Age. Journal of Acoustical Society of America, 86(4), 1384-1391.

75. Gundersen,T., Homoen K. (1976). Cited in Mair, I.W.S and Hallmo. P. (1994). Myringoplasty : A Conventional and Extended High Frequency Air and Bone Conduction Audiometric Study. Scandinavinan Audiology, 23 (3) 205-208.

76. Gupta, A., Govil, S., Saoji, A., R., Binu, R., Burman, A. (1999). Age related Changes on High Frequency Audiometry. Paper Presented at 31st National Conference of Indian Speech and Hearing Association, Chandigarh.

77. Hagewald, M., Heitman, R., Wiederhold, M.L., Cooper, J.C., Gates, G.A. (1989). Cited in Hallmo, P., Mair, I.W.S. (1996). Drilling in Ear Surgery- A comparsion of Pre- and Post-Operative Bone- Conduction Thresholds in Both the Conventional and Extended High Frequency Ranges. Scandinavian Audiology, 25, 35- 38.

78. Hallmo, P. (1997). Extended High-Frequency Audiometry in Traumatic Membrane Perforations. Scandinavian Audiology, 26(1), 53-59.

79. . Hallmo, P., Borchgrevink, Mair, I.W.S. (1995). Extended High Frequency Thresholds in Noise-Induced Hearing Loss. Scandinavian Audiology, 24(1), 47-52.

80. Hallmo, P., Mair, I.W.S. (1996). Drilling in Ear Surgery : A comparison of Pre - and Post-operative Bone-Conduction Thresholds in Both the Conventional and Extended High-Frequency Ranges. Scandinavian Audiology , 25, 35-38.

81. Hallmo, P., Sundby, A., Mair, I.W.S. (1994). Extended High-frequency Audiometry : Air and Bone Conduction Thresholds, Age and Gender Variations, Scandinavian Audiology, 23(3), 165-170.

82. Hallmo, P., Sundby, A., Mair, I.W.S.(1992). High Frequency Audiometry : Masking of Air- and Bone Conduction Signals. Scandinavian Audiology, 21(2), 115-121.

83. Hallomo, P., Sundby, A., Mair, I.W.S (1991). High Frequency Audiometry : Response Characteristics of the KH 70 Vibrator. Scandinavian Audiology. 20(2). 139-43. Cited in Scientific Update

and News Scan. Sun Pharmaceutical Industries Limited, Gujarat, India.

84. Han, L.A., Poulsen, T. (1998). Equivalent Threshold Sound Pressure Levels for Scennheiser HDA 200 Earphone and Etymotic Research ER-2 Insert Earphonw in the Frequency Range 125 Hz to 16 KHz. Scandinavian Audiology, 27(2), 105-112.

85. Hanner, P., Axelsson, A. (1988). Cited in Hallmo, P.. Borchgrevink, H.M., Mair, I.W.S. (1995). Extended High Frequency Thresholds in Noise Induced Hearing Loss. Scandinavian Audiology. 24, 47-52.

86. Hansen, T.S., Brask, T. Larsen, S. (1993). High-Frequency Air-conduction Audiometry : Testing of a New Low Impedance Circumaural Transducer System in Normal Young Persons. Scandinavian Audiology, 22(1), 37-42.

87. Harris, J.D., Myers, C.K (1971). Cited in P.A. Yantis. (1994). Puretone Air-Conduction Threshold Testing. In J. Katz. (Ed.). Handbook of Clinical Audiology, 4th Edn. pp. 97-108. Baltimore : Williams and Wilkins.

88. Harris, J.D., Ward, M.D., Cited in P.A. Yantis, (1994). Puretone Air-Conduction Threshold Testing. In J. Katz, (Ed.). Handbook of Clinical Audiology, 4th Edn. pp. 97-108. Baltimore : Williams and Wilkins.

89. Helms, J. (1976).Cited in Hallmo, P., Mair, I.W.S. (1996). Drilling in Ear Surgery- A Camparison of Pre- and Post-Operative Bone-Conduction Thresholds in Both the Conventional and Extended High Frequency Ranges. Scandinavian Audiology, 25, 35-38.

90. Helson, L., Okonkwo E, Anton, L. (1978). Cited in Dreschler. W.A., Vander Hulst, R.J.A.M., Tange, R.A., Urbanus, N.A.M. (1989). Role of High Frequency Audiometry in the Early Detection of Ototoxicity. II Clinical Aspects. Audiology 28 (4) 211-220.

91. Henry, K.R., Fast, G.A., Nguyen, H.H., Paolinelli. M.C., Ayars. N.M. (1985). Cited in Trehub, S.E., Schneider, B.A., Morrongiello. B.A., Thorpe LA, (1989). Developmental Changes in High Frequency Sensitivity. Audiology, 28, 241-249.

92. Hickey, S.A., O'Connor, A.F.F. (1991), Citied in Hallmo P, Mair IWS. (1996). Drilling in Ear Surgery - A Comparison of Pre - and Post- Operative Bone- Conduction Thresholds in Both the Conventional and Extended High-Frequency Ranges. Scandinavian Audiology, 25, 35-38.

93. Holmquist, J., Oleander, R., Hallen, O. (1979). Citied in Hallmo P, Mair IWS (1996). Drilling in Ear Surgery - A comparison of Pre - and Post- Operative Bone-Conduction Thresholds in Both the Conventional and Extended High-Frequency Ranges. Scandinavian Audiology, 25, 35-38.

94. Hulka, J.H. (1941). Cited in Margolis, R.H.. Hunter L.L. Rykken. J.R. Giebink, S.G (1993). Effects of Otitis Media on Extended High Frequency Hearing in Children. Annals of Otology, Rhinology and Laryngology, 102, 1-5.

95. Jacobson, E.J., Downs, M.P., Fletcher, J.L. (1969). Cited in Dreschler, W.A., Van Der Hulst, R.J.A.M., Range, R.A., Urbaenus. N.A.M.

(1989). Role of High Frequency audiometry on the Early Detection of Ototoxicity. II Clinical Aspects. Audiology. 28(4). 211-220.

96. Johnson, L.G., Hawkins, J.E., Jr. (1972). Cited in Trehub, S.E., Schneider, B.A., Morrongiello, B.A., Thorpe, L.A. (1989). Developmental Changes in High Frequency Sensitivity. Audiology. 28,241-249.

97. Katz, J. Eds (1994). Handbook of Clinical Audiology, 4th Edn. Baltimore : Williams and Willons.

98. Khanna S.M, Tonndof J (1972). Cited in Mair, I.W.S Fjermedal O., Laukli, E (1989). Air Conduction Thresholds and Secretory Otitis Media : A Conventional and Extra-High Frequency Audiometric Comparison. Annals of Otology, Rhinology and Laryngology, 98, 767-771.

99. Kiukaanniemi, H. (1980) Cited in Shaw G.M, Jardusie C A and Freidjhon P. (1996). A Pilot Investigation of High - Frequency Audiometry in Obscure Auditory Dysfunction (OAD) Patients. British Journal of Audiology, 30, 233-237.

100. Konraddson, K.S., Ivarsson, A., Bank G (1987). Cited in Mair, I.W.S. Fjermedal, O., Laukli, E (1989). Air Conduction Thresholds and Secretory Otitis Media : a Conventional and Extra-High Frequency Audiometric Comparison. Annals of Otalogy, Rhinology and Laryngology, 98, 767-771.

101. Kopelman J, Budnick AS, Sessions RB, Kramer MB, Wong GY. (1988). cited in Fausti SA, Henry JA, Schaffer HI, Olson DJ, Frey

RH, Bagby GC. (1993). High Frequency Monitoring Gor Early Detection of Cisplatin Ototoxicity. Archives of Otolaryngology Head Neck surgery, 119, 661-666.

102. Kurman, B (Personal Communication 1988) Cited in Silman, S and Silverman, C.A. (1991). Auditory Diagnosis : Principles and Applications, pp. 10-70. California: Academic Press, Inc.

103. Kylen, P., Arlinger, S.D. (1976). Cited in Hallmo P, Mair I.W.S. (1996). Drilling in Ear Surgery-Acauparison of Pre- and Post-Operative Bone-Conduction Thresholds in Both the Conventional and Extended High -Frequency Ranges. Scandianavian Audiology, 25, 35 -38.

104. Kylen, P., Arlinger, S.D., Bergholtz, L.M. (1977). Citied in Hallmo P, Mair IWS. (1996). Drilling in Ear Surgery - A Comparison of Pre- and Post- Operative Bone-Conduction Thresholds in Both the Conventional and Extended High Frequency Ranges. Scandinavian Audiology, 25, 35-38.

105. Laitila, P., Karma, P., Sipila, M., Manniner, M., Rakho, T. (1997). Extended High Frequency Hearing and History of Acute Otitis Media in 14 Year Old Children in Finland. Acta Otoloryngolica (Stockhelm). Supplement 529. 27-29.

106. Laukli, E, Mair. I.W.S. (1985) Cited in Silman, S., Silverman, C.A. (1991). Auditory Diagnosis : Principles and Applications, pp. 10-70, California : Academic Press, Inc.

107. Levine, B.A, Shelton C, Berliner, K.I., Sheehy, J.L. (1989). Cited inMargolis, R.H., Hunter L.L., Rykken, J.R., Giebink, S.G, (1993). Effects of Otitis Media on Extended High-Frequency Hearing in Children. Annals of Otology, Rhinology and Laryngology, 102, 1-5.

108. Lim, D.J. (1970). Cited in Mair, I.W.S and Hallmo (P) 1994 Myringoplasty : A Conventional and Extended High Frequency Air and Bone Conduction Audiometeric Study. Scandionavian Audiology, 23 (3), 205-208.

109. Lopponen, H. (1992). High Frequency Audiometry : Masking in Electric Bone Conduction Audiometry. Scandinavian Audiology, 21(1), 31-35.

110. Lopponen, H., Laitakari, K., Sorri, M (1991) High Frquency Audiometry : Accelerometric Findings With Electric Bone Conduction Audiometry. Scandinavian Audiology. 20(2). 61-7 Cited in Scientific Update and Newscan. Sun Pharmaceutical Industries Limited. Gujarat, India.

111. Lopponen, H., Sorri, M., Bloigu, R. (1991). High-frequency Air Conduction and Electric Bone-Conduction Audiometry : Age and Sex Variations. Scandinavian Audiology, 20 (3), 181-189.

112. Lopponen, H., Sorri, M. (1991). High Frequency Air-Conduction and Electric Bone-Conduction Audiometry : Comparison of Two Methods. Scandinavian Audiology, 20 (3), 175-180.

113. Lutman, M.E. (1984). Citied in Reynolds, L., Morton. L.P. (1995). Acoustic Reflex Measures at High Probe Frequency : A Phasor Diagram Approach. British Journal of Audiology, 29, 144-152.

114. Lutman, M.E., Martin, A.M. (1979) Cited in Reynolds L and Morton L P (1995). Acoustic Reflex Measures at High Probe Frequency : A Phasa Diagram Approach. British Journal of Audiology. 29. 144-152.

115. Lutman, M.E., McKenzie, H., Swan, I.R.C. (1984). Cited in Reynolds L and Morton LP. (1995). Acoustic Reflex Measures at High Probe Frequency : a Phasor Diagram Approach. British Journal of Audiology, 29, 144-152.

116. Luts, A. (1982). Cited in Filipo, R., De Seta, E. and Bertoli. G.A. (1988). High- Frequency Audiometry in Children. Scandinavian Audiology. 17,213-216.

117. Mair, I.W.S., Laukli, E. (1986). Cited in Hallmo P, Mans IWS. (1996). Drilling in Ear Surgery- A Comparison of Pre- and Post-Operative Bone-Conduction Thresholds in Both the Conventional and Extended High Frequency Ranges. Scandinavian Audiology. 25. 35-38.

118. Mair, I.W.S., Fjermedal, O., Laukli, E. (1989). Air Conduction Thresholds and Secretory Otitis Media : A Conventional and Extra - High Frequency Audiometric Comparison. Annals of Otology, Rhinology and Laryngology, 98, 767-771.

119. Mair, I.W.S., Hallmo, P. (1994). Myringoplasty : A Conventional and Extended High Frequency, Air- and Bone- Conduction Audiometric Study. Scandinavian Audiology. 23(3). 205-208.

120. Mair. I.W.S., Shoel, P., Elverland, H.H (1989). Cited in Margolis. R.H., Hunter L.L., Rykken, J.R., Gicbink, S.G (1993). Effects of Otitis Media on Extended High-frequency Hearing in Children. Annals of Otology Rhinoloyg and Laryngology, 102 () 1-5.

121. Margolis, R.H., Heller, J.W (1987). Cited in Margolis. R.H., Hunter L.L., Rykken, J.R., Giebink, S.G (1993). Effects of Otitis Media on Extended High-Frequency Wearing in Children. Annals of Otology, Rhinology and Laryngology, 102,1-5.

122. Margolis, R.H., Hunter, L.L., Ryken, J.R.. Giebink, S.G. (1993). Effect of Otitis Media on Extended High-Frequency Hearing in Children. Annal of Otology, Rhinology and Laryngology, 102, 1-5.

123. Matthews, L.J, Lee. F.S., Mills, J.H., Dubno. J.R. (1997). Extended high - Frequency Thresholds in Older Adults. Journal of Speech, Language and Hearing Research, 40, 208-214.

124. Matz. G.J. (1990). cited in Fausti, S.A., Olson, D.J., Frey, R.H., Henry. J.A., Schaffer, H.I. (1993). High-Frequency Tone Burst-Evoked ABR Latency - Intensity Functions. Scandinavian Audiology, 22(1), 25-33.

125. Me Dermott, J.C., Fausti, S.A., Frey R.H. (1986). Cited in Morgolis R.H., Hunter L.L, Rykken, J.R., Giebink S.G (1993). Effects of Otitis

Media on Extended High-Frequency Hearing in Children. Annals of Otology, Rhinology and Laryngology, 102, 1-5.

126. Mc Dermott, J.C., Faustic, S.A., Henry, J.A., Frey, R.H. (1990). Effects of Contralateral Masking on High-Frequency Bone-Conduction Thresholds. Audiology. 29(6)297-303.

127. Moore, B.C. (1985). Cited in Shaw G M. Jardene, CA. Fridjhon P. (1996). A Pilot Investigation of High-Frequency Audiometry in Obscure Auditory Dysfunction (OAD) Patients. British Journal of Audiology, 30, 233-237.

128. Morton, L.P, Reynold, L. (1991). High Frequency Thresholds Variations with Age and Industrial noise- Exposure. South African Journal of Communication Disorders. 38.13-17 Cited in Scientific Update and Newscan, Sun Pharmaceutical Industries Limited. Gujarat, India.

129. Mitchell, C.R., Phillips, D.S., Trune, D.R. (1989). cited in Fausti. S.A., Frey, R.H., Henry, J.A., Olson, D.J. (1992). Comparing Laboratory and Portable Tone - Burst Auditory Brain - Stem - Response (ABR) Systems for Monitoring High - Frequency (> - 8 KHz) Auditory Function. Scandinavian Audiology, 21,211-217.

130. Myers, C.K., Harris, J.D. (1970). Cited in P.A. Yantis, (1994). Puretone Air-Conduction Threshold Testing. In J. Katz. (Ed.). Handbook of Clinical Audiology. 4th Edn. pp.97-108. Baltimore : Williams and Wilkins.

131. Northern, J., Davis, M.P. , Rudmose, W., Glorig, A.. Fletcher, J.L. (1972). Cited in P.A. Yantis. (1994). Puretone Air-Conduction Threshold Testing. In J. Katz. (Ed.). Handbook of Clinical Audiology. 4th Edn. pp. 97-108. Baltimore: Williams and Wilkins.

132. Okstad, S., Laukli, E., and Mair, I.W. (1988) Cited in L.A. Wilber. (1991). Puretone Audiometry : Air- and Bone - Conduction. In W.F. Rintelmann, (Edn.). Hearing Assessment. 2nd Edn. pp. 1-38. Massachusetts : Allyn and Bacon, a division of Simon and Schuster, Inc.

133. Osterhammel, D. (1980). Cited in Filipo, R., De Seta, E. and Bertoli. G.A. (1988). High-Frequency Audiometry in Children. Scandinavian Audiology, 17,213-216.

134. Osterhammel, D. (1978). Cited in P.A.Yantis, (1994). Puretone Air-Conduction Threshold Testing. In J. Katz. (Edn.), Handbook of Clinical Audiology. 97-108. Baltimore. Williams and Wilkins.

135. Osterhammel, D. (1979). Cited in Filipo, R., De Seta, E. and Bertoli, G.A. (1988). High-Frequency Audiometry in Children. Scandinavian Audiology, 17, 213-216.

136. Osterhammel, D., Christau, B. (1980). Cited in Filipo. R., De Seta, E. and Bertoli, G.A. (1988). High-Frequency Audiometry in Children. Scandinavian Audiology, 17, 213-216.

137. Pollera, C.F., Marollo, P., Nardi, M., Ameglio, F., Cozzo, L., Bevere. F. (1988). Cited in Fausti, S.A., Henry, J.A., Schaffer, H.I., Olson, D.J., Frey, R.H., Bagby, G.C. (1993). High Frequency Monitoring for

Early Detection of Cisplatin Ototoxicity. Archives of Otolaryngology Head Neck Surgery, 119,661 -666.

138. Palva, A.. Sorri, M. (1979) Cited in Hallmo, P., Mair, I.W.S. (1996). Drilling in Ear Surgery - A Comparison of Pre- and Post-Operative Bone-Conduction Thresholds in Both the Conventional and Extended High Frequency Ranges. Scandinavian Audiology, 28, 35-38.

139. Paperella M.M., Brady, D.R., Hoel R (1970). Cited in Margolis, R.H.. Hunter, L.L., Rykken J.R., Giebink S.G (1993). Effects of Otitis Media Extended High-Frequency Hearing in Children. Annals of Ototogy, Rhinology and Laryngology, 102, 1-5.

140. Parkin, J.L., Wood, G.S., Wood, R.D., McCandless, G.A. (1980). Cited in Hallmo P, Mair, I.W.S. (1996). Drilling in Ear Surgery- A Comparison of Pre-and Post-Operative Base-Conduction Thresholds in Both the Conventional and Extended High-Frequency Ranges. Scandinavian Audiology, 25, 35-38.

141. Piel, I.A., Meyer D., Perlia, Ch. P., et al (1974). Cited in Dreschler W.A., Vander Hulst, R.J.A.M., Tange, R.A., Urbanus. N.A.M. (1989). Role of High Frequency Audiometry in the Early Detection of Ototoxicity. II Clinical Aspects. Audiology, 28 (4), 211-220.

142. Radhika, S. (1988). High Frequency Audiometry - A Review. Unpublished Masters Dissertation. University of Mysore, India.

143. Rakho, T., Karma, P. (1986) Cited in L.A. Wilber. (1991). Puretone Audiometry : Air - and Bone - Conduction. In W.F. Rintelmann.

(Ed.)- Hearing Assessment. 2nd End. 1-38. Massachusetts. Allyn and Bacon, A Division of Simon and Schuster, Inc.

144. Rappaport, B.Z., Fausti, S.A., Schechter, M.A., Frey, R.H. (1986). Cited in Trehub, S,E,, Schneider, B.A., Morrongiello. B.A., Thorpe, L.A., (1989). Developmental Changes in High Frequency Sensitivity. Audiology, 28, 241-249.

145. Rappaport, B.Z., Fausti, S.A., Schechter, M.A., Frey. R.H. (1982). Cited in Mc Dermott, J.C., Fausti, S.A., Henry, J.A., Frey, R.H. (1990). Effects of Contralateral Marking on High-Frequency Bone Conduction Thresholds. Audiology, 29, 297-303.

146. Rappaport, B.Z., Fausti, S.A., Schecheter, M.A., Frey. R.H. (1986). Cited in L.A. Wilber. (1991). Puretone Audiometry : Air - And Bone - Conduction. In W.F. Rintelmann, (Ed.). Hearing Assessment.2nd Edn. pp. 1-38. Massachusetts, Allyn and Bacon, A Division of Simon and Schuster, Inc.

147. Rintelmann, W.F. (1991). Hearing Assessment. Massachusetts : Allyn and Baxon, A Division of Simon and Schuster Inc.

148. Reynolds, L., Morton, L.P. (1995). Acoustic Reflex Measures at High Probe Frequency : A Phasor Diagram Approach. British Journal of Audiology, 29, 144-152.

149. Richter, U., Frank, T. (1985). Cited in Silman, S., Silverman, C.A. (1991). Auditory diagnosis : Principles and Applications. pp. 10-70. California : Academic Press, Inc.

150. Richter, U. (1992). Cited in Han, L.A., Poulsen, T. (1998). Equivalent Threshold Sound Pressure Levels of Sennheiser, H.D.A. 200 Earphone and Etymotic Research ER-2. Insert Earphone in the Frequency Range 125 Hz to 16 kHz. Scandinavian Audiology, 27, 105-112.

151. Richter, U. (1993). Cited in Han, L.A., Poulsen, T. (1998). Equivalent Threshold Sound Pressure Levels of Sennheiser. H.D.A. 200 Earphone and Etymotic Research ER-2. Insert Earphone in the Frequency Range 125 Hz to 16 kHz. Scandinavian Audiology. 27, 105-112.

152. Richter< U (1997). Cited in Han, L.A., Poulsen, T. (1998). Equivalent Threshold Sound Pressure Levels of Sennheiser. H.D.A. 200 Earphone and Etymotic Research ER-2. Insert Earphone in the Frequency Range 125 Hz to 16 kHz. Scandinavian Audiology. 27, 105-112.

153. Robertson, R.M., Williams, C.E. (1975). Cited in Filpo. R., De Seta. E. and Bertoli, G.A. (1988). High-Frequency Audiometry in Children. Scandinavian Audiology, 17,213-216.

154. Rosen, S., Plester, D., E1-Mofty, A., Rosen, H.V. (1964). Cited in Lopponen H, Sorri M, Bloigu R. (1991). High Frequency Air Conduction and Electric Bone Conduction Audiometry : Age and Sex Variations. Scandinavian Audiology, 20, 181-189.

155. Rosen, S., Olin, P. (1965). cited in Filipo, R., De Seta, E. and Bertoli, G.A. (1988). High-frequency audiometry in children. Scandinavian Audiology, 17,213-216.

156. Rossof, A.H., Slayton, R.E., Perlia, C.P. (1972). Cited in Fausti, S.A., Henry, J.A., Schaffer, H.I., Olson, D.J., Frey, R.H., Bagby, G.C.. (1993). High Frequency Monitoring for Early Detection of Cisplatin Ototoxicity. Archives of Otolaryngology Head Neck Surgery, 119. 661-666.

157. Sakamoto, M, Sugasawa, M., Kaga, K., Kamio, T. (1998). Average Thresholds in the 8 to 20 kHz Range in Young Adults. Scandinavian Audiology, 27(3), 169-172.

158. Sakamoto, M., Sugasawa, M, Kaga K., Kamio, T. (1998). Average Thresholds in the 8 - to 20- kHz Range as a Function of Age. Scandinavian Audiology. 27(3). 189-192.

159. Sataloff, R.T., Sataloff, J.(1993). Hearing Loss. 3 rd Edn. New York : Marcel Dekker, Inc.

160. Sataloff, J., Vassallo, L., Menduke, H. (1967). Cited in Filipo, R.. De Seta, E. and Bertoli, G.A. (1988). High-Frequency Audiometry in Children. Scandinavian Audiology, 17,213-216.

161. Saunders, J.C., Kaltenbach, J.A, Relkin, E.M. (1983). Cited in Trehub, S,E, Schneider, B,A, Morrongiello, B,A, Thorpe, L.A. (1989). Developmental Changes in High Frequency Sensitivity. Audiology, 28, 241-249.

162. Schechter, A.M., Fausti, S.A., Rappaport, B.Z., Frey, R.H. (1986). Cited in Stelmachowiez, P.G., Beauchaine, K.A., Kalberer, A., Jesteadt, W. (1989). Normative Thresholds in the 8 to 20 kHz Range

as a Function of Age. Journal of Acoustical Society of America, 86(4), 1384- 1391.

163. Shaw, G.M., Jardinc, C.A., Fridjhon, P. (1996). A Pilot Investigation of High-Frequency Audiometry in Obscure Auditory Dysfunction (OAD) Patients. British Journal of Audiology, 30, 233 -237.

164. Shaw, G.M. (1974). Cited in Trehub, S.E., Schneider. B.A., Morrongiello, B.A., Thorpe, L.A., (1989). Developmental Changes in High Frequency Sensitivity. Audiology, 28, 241-249.

165. Silman, S., Silverman, C.A, (1991). Audiotory Diagnosis, Principles and Applications. California : Academic Press, Inc.

166. Stelmacholwicz, P.G., Beavchanine, K.A., Kalberer, A., Jesteadt. W. (1989). Normative Thresholds in the 8 to 20 kHz Range as a Function of Age. Journal of Acoustical Society of America, 86; 1384-91.

167. Stelmachowicz, P.G., Beauchaine, KA., Kalberer, A., Langer. T., Jesteadt, W. (1988). The Reliability of Auditorythresholds in the 8-to 20-kHz Range Using a Prototype Audiometer. Journal of Acoustical Society of America, 83(4), 1528-1535.

. 168. Stelmachowicz, P.G., Beauchaine, K.A., Kalberer, A., Kelly. W.J.., Jesteadt, W. (1989). High - Frequency Audiometry : Test Reliability and Procedural Considerations. Journal of Acoustical Society of America, 85, 879 -87.

169. Stevens, S.N. Berkovitz, R., Kidd, G.Jr., and Green, D.M. (1987). Cited in Stelmachowicz. P.G., Beauchaine, K.A., Kalberer. A., Jesteadt W. (1989). Normative Thresholds in the 8 to 20 kHz Range

as a Function of Age. Journal of Acoustical Society of America. 86(4), 1384-1391.

170. Takeshima, H., Suzuki, Y., Kumagai, M., Sone, T., Fujinori. T., Miura, H. (1995). Cited in Han, L.A., Poulsen, T. (1998). Equivalent Threshold Sound Pressure Levels of Sennheiser, H.D.A. 200 Earphone and Etymotic Research ER-2. Insert Earphone in the Frequency Range 125 Hz to 16 kHz. Scandinavian Audiology. 27, 105-112.

171. Tange R.A (1984). Cited in Dreschler, W.A, Vander Hulst, R.J.A.M.. Urbanus, N.A.M., (1988). High Frequency Audiometry in Prospective Clinical Research of Ototoxicity Due to Platinum Derivatives. Annals of Otology, Rhinology and Laryngology, 97, 133-137.

172. Tange, R.A., Dreschler, W.A. (1992). Predictive Value of High Frequency Audiometery in Otosclerosis Rev Laryngol- Otol - Rhino1 - Bord. 113 (2) 91-93 Cited in Scientific Update and News Scan, Sun Pharmaceutical Industries Limited, Gujarat, India.

173. Tange, R.A., Conijn, E.A.G., Van Zeyl, L.P.G. (1982). Cited in Dreschler, W.A., Van der Hulst, R.J.A.M., Tange, R.A., Urbanus, N.A.M. (1989). Role of High Frequency Audiometry on the Early Detection of Ototoxicity. II Clinical Aspects. Audiology, 28(4), 211-220.

174. Tange, R.A., Dreschler, WA., Van der Hulst, R.J.A.M., (1985). Cited in Dreschler, W.A., Van der Hulst, R.J.A.M., Range, R.A., urbenus, N.A.M. (1989). Role of High Frequency Audiometry on the Early Detection of Toxicity. II Clinical Aspects. Audiology, 28(4), 211-220.

175. Thorton, A.R.D., Bell, I.E., Phillipps, J.J. (1989). High-Frequency Monitoring Using an Electrostimulation Audiometer. Bristish Journal of Audiology, 23, 63-68.

176. Tonndorf, J., Kurman, B. (1984). Cited in Silman, S., Silverman, C.A. (1991). Auditory Diagnosis : Principles and Applications, pp. 10-70. California : Academic Press, Inc.

177. Tonndorf, J. (1985). Cited in Silman, S., Silverman, C.A. (1991). Auditory Diagnosis : Principles and Applications. pp 10-70. California: Academic Press, Inc.

178. Tonndorf, J., Khanna, S.M. (1972). Cited in Margolis, R.H., Hunter. L.L., Rykken, J.R, Giebink, S.G. (1993). Effects of Otitis Media on Extended High Frequency Hearing in Children. Annals of Otology, Rhinology and Laryngology, 102 , 1-5.

179. Tonndorf, J. (Personal communication, 1987). Cited in Silman. S.. Silverman, C.A. (1991). Auditory Diagnosis : Principles and Application, pp 10-70. California. Academic Press. Inc.

180. Tos, M., Trojaborg, N., Thomsen, J. (1989). Cited in Hallmo P, Mair IWS. (1996). Drilling in Ear Surgery - A Comparison of Pre - and Post-Operative Bone-Conduction Thresholds in Both the Conventional and Extended High Frequency Ranges. Scandinavian Audiology, 25, 35-38.

181. Trehub, S.E., Schneider, B.A., Morrongiello, B.A., Thorpe, L.A. (1989). Developmental Changes in High-Frequency Sensitivity. Audiology. 28(5), 241-249.

182. Tyler, R.S. Wood, E.J., Fernandes, M., et al. (1982). Cited in Shaw GM, Jardine C A, Fridjhon P. (1996). A Pilot Investigation of High-Frequency Audiometry in Obscure Auditory Dysfunction (OAD) Patients. British Journal of Audiology, 30, 233-237.

183. Valente, M.. Potts, L.G., Valente, M-St-George, M., Goebel, J. (1992). High Frequency Thresholds : Sound Suite Versus Hospital Room. Journal of American Academic Audiology. 3(4). 287-294. Citied in Scientific Update and News Scan. Sun Phasmaceutical Industries Limited. Gujurat, India.

184. Van Zeyl, L.P.G.M., Conijn, E.A.J.G., Rodenberg, M.. et al. (1984). Cited in Dreschler, W.A., Van der Hulst, R.J.A.M., Range, R.A.. Urbenus, N.A.M. 919890. Role of High Frequency Audiometry on the Early Detection of Ototoxicity. II Clinical Aspects. Audiology. 28(4). 211-220.

185. Vander Hulst, R.J.A.M., Dreschler, W.A., and Urbanus. N.A. (1988). Cited in L.A. Wilber, (1991). Puretone Audiometry : Air - and bone - Conduction. In W.F. Rintelmann, (Ed.). Hearing Assessment. 2nd Edn. pp. 1-38. Massachusetts, Allyn and Bacon, a Division of Simon and Schuster, Inc.

186. Vanhuyse, V.J., Creten W.L., VanCamp, K.J (1975). Cited in Margolis, R.H., Hunter, L.L., Rykken, J.R., Giebink. S.G (1993). Effects of Otitis Media on Extended High Frequency Hearing in Children. Annals of Otology, Rhinology and Laryngology, 102, 1-5.

187. Verbist, M., Debruyne, F., Feenstra, E.R.L. (1993). Cited in Hallmo P, Mair, I.W.S. (1996). Drilling in Ear Surgery - A Comparison of Pre- and Post-Operative Bone-Conduction Thresholds in Both the Conventional and Extended High Frequency Ranges. Scandinavian Audiology, 25, 35-38.

188. Waters, G.S., Ahmad, M., Katsarkas, A., Stamimir, G., McKay. J. (1991). Cited in Fausti, S.A., Henry, J.A., Schaffer, H.I., Olson, D.J., Frey, R.H., Bagby, G.C. (1993). High Frequency Monitoring for Early Detection of Cisplatin Ototoxicity. Archives of Otolaryngology Head Neck Surgery, 119, 661-666.

189. Wegel, R.L. (1932). Physical Data and Physiology of Excitation of the Auditory Nerve. Annals of Otology, Rhinology and Laryngology. 41, 740-779, Cited in Assessing the Feasibility of HFA Through the Collection of Hormative Threshold Data above 8000 Hz. Speech and Hearing Science Research Reports. (1971).

190. Wetmore, R.F. Henry, W.J., Konkle, D.F. (1993). Cited in Hallmo P, Mair, I.W.S. (1996). Drilling in Ear Surgery - A Comparison of Pre- and Post-Operative Bone-Conduction Threshold in both the Conventional and Extended High-frequency Ranges. Scandinavian Audiology, 25, 35-38.

191. Willams, K.R., Lesser, T.H.J (1990). Cited in Mair I.W.S and Hallmo P. (1994). Myringoplasy : a Conventional and Extended High-Frequency Air and Bone Conduction Audiometric Study. Scandinavian Audiology. 23 (3) 205-208.

192. Zislis, T., Flecther, J.L. (1966). Cited in P.A. Yantis. (1994). Puretone Air-Conduction Threshold Testing. In J. Katz, (Ed.). Handbook of Clinical Audiology. 4th Edn. pp. 97-108. Baltimore : Williams and Wilkins.