COMPARISON OF SIGNAL TO NOISE RATIO OF CLICKS AND TONE BURSTS EVOKED OTOACOUSTIC EMISSIONS IN NORMALS AND IN PATIENTS WITH DIFFERENT MAGNITUDE OF HEARING LOSS

Register No. M9909

An Independent Project Submitted as part fulfillment
for the First year M.Sc. (Speech & Hearing) to University of Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING, MYSORE-570006
MAY-2000

Dedicated To

Periyamma, Aiya, Babu mama

and Selva mama

With Love

Certificate

This is to certify that the independent Project entitled "Comparision of Signal to Noise Ratio of Clicks and Tone Bursts Evoked Otoacoustic Emissions in Normals and in Patients with Different Magnitude of Hearing loss" is the bonafide work done in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with Register' No.

Mysore
May, 2000.

Director
All India Institute of
Speech & Hearing,
Mysore - 570006

Certificate

This is to certify that the independent project entitled "Comparision of Signal to Noise Ratio of Clicks and Tone Bursts Evoked Otoacoustic Emissions in Normals and in Patients with Different Magnitude of Hearing loss" has been prepared under my supervision and guidance.

Mysore.
May: 2000.

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Declaration

I hereby declare that this independent Project entitled "Comparision of Signal to Noise Ratio of Clicks and Tone Bursts Evoked Otoacoustic Emissions in Normals and in Patients with Different Magnitude of Hearing loss" is the result of my own study under the guidance of Mr. Animesh Burman, Lecturer, department of Audiology, All India institute of (Speech and Hearing, ^Mysore, and has not been submitted earlier at any other University for any other diploma or degree.

Mysore. Register-No.M9909

May,2000

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You have been there with me in fun, laughter, and grief.............

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INTRODUCTION

Otoacoustic emissions (OAEs) are potentially a valuable noninvasive, objective, clinical as well as research tool for evaluating cochlear status (Kemp, 1978 ; Johnsen, Bage & Elberling, 1983 ; Elberling, Parbo, Johnsen & Bage, 1985 ; Kemp, Bray, Alexander & Brown, 1986 ; Bonfils, Uziel & Pujol, 1988 ; Lutman, Manson, Sheppard & Gibbin, 1989). These are sounds found in the external auditory meatus that originate in physiologically vital and vulnerable activity inside the cochlea and are generated either spontaneously or in response to acoustic stimulation (Kemp, 1978). This was first reported by Kemp in 1978.

The emissions or sounds generated by cochlea are small but potentially audible, sometimes amounting to as much as 30 dB SPL (Kemp, 1978). OAEs are a property of healthy normal functioning cochlea, generated by active frequency selective, non linear elements within the cochlear partition, the critical components being the outer haircells (Kemp, 1988). When the outer hair cells are structurally damaged or nonfunctional, otoacoustic emissions can not be evoked by acoustic stimuli (Norton, 1993).

The presence of evoked otoacoustic emissions has proven to be evidence of a normal functioning cochlea and peripheral hearing system. Emissions are absent in the presence of conductive hearing impairment and significant sensory neural hearing loss (Anderson & Kemp, 1979). No transient evoked otoacoustic emissions could be obtained from ears when the cochlear hearing impairment exceeds 50 dBHL (Stover & Norton, 1994).

Among the evoked acoustic emissions, there are three types based primarily on the stimuli used to evoke them. They are :

i) Transient evoked emissions (TEOAEs)

ii) Acoustic distortion product emissions (DPOAEs)

iii) Stimulus frequency emissions (SFOAEs)

TEOAEs are frequency dispersive responses following a brief acoustic stimuli such as click or toneburst (Kemp, 1978 ; Norton & Neely, 1987). They are complex acoustic events that can be recorded in nearly all persons who have normal hearing (Glattke & Robinette, 1997). OAEs have been used to address a variety of clinical issues including

1. Neonatal hearing screening (White, Vohr & Behrens, 1993).
2. Pediatric assessment (Norton, 1993).
3. Adult assessment (Musiek, Smurzynski & Bornstein, 1994).
4. Evaluation of patients with developmental durability (Gorga, Stover, Bergman, Beaucharn & Kaminiski, 1995).
5. Neurologic assessments (Robinette, Bauch, Olsen, Harner & Beamy, 1992).
6. Ototoxic monitoring (Hotz, Harris & Probst, 1994).
7. Predict audiogram pattern (Fuse, Aoyage, Suzuki & Koike, 1994).

For the common clinical application of TEOAEs,click stimulus is presented at moderate intensities (80 dB SPL or 45 dB above perceptual threshold). TEOAEs obtained in response to click stimuli are expected to have broad response spectra and they maximize the probability of detecting a response after a brief sampling period. The emerging normative data indicate that the most effective stimulus and the most robust response components are found in the mid-frequency region.

Luteman, Mason, Sheppard & Gibbin, (1989) opined that the presence of a click evoked otoacoustic emission (CEOAEs) is a powerful indicator of normal hearing.

Transient evoked otoacoustic emissions can also be evoked using tone-bursts (TBOAEs) which have narrower band width and energy concentrated around the center frequency of the toneburst. Fourier analysis of TBOAEs indicates mat their spectral composition is similar to that of the evoking toneburst (Norton & Neely, 1987 ; Stover & Norton, 1993).

The emissions in response to tone burst are quite frequency specific. Tone burst emissions were often prominent than click evoked otoacoustic emissions (CEOAEs) and at the frequencies of spontaneous otoacoustic emissions, prominent peaks in both clicks & tone bursts evoked otoacoustic emissions were present (Probst, Coats, Martin & Lonsburry-Martm, 1986).

Both clicks and tonebursts stimuli for eliciting responses in ears with and without hearing loss have shown no significant advantage of using tone burst as stimuli (Kemp et al., 1986 ; Norton & Neely, 1987; Harris & Probst, 1991; Probst & Harris, 1993). But TBOAE amplitude is highest in the 1000 Hz band (Stover & Norton, 1993 ; Prieve et al., 1996).

The only advantage of tone burst stimulus is that more energy can be introduced in a specific frequency range than is possible for an equivalent click, which is a more frequency dispersive stimuli.

TEOAEs cannot be recorded when an individual has a hearing loss exceeding(a) 25 to 30 dBHL (Kemp, 1978 ; Probst, Lonsbury - Martin, Martin & Coats, 1987 ; Bonfils & Uziel, 1989) (b) 30 dBHL (Robinette, 1992) (c) 50 dBHL . (Norton and Stover, 1994).

The ability of TEOAE (clicks & tonebursts), response parameters such as amplitude, signal to noise ratio and reproducibility rate to identify hearing loss of varying degrees have also been studied (Probst,Coats, Martin & Lonsbury- Martin, 1986 ; Prieve et al, 1993 ; Hurley & Musiek, 1994 ; Herer, Glattke, Pafits & Cummiskey, 1996 ; Prieve, Gorga & Neely, 1996).

Click evoked otoacoustic emissions were difficult to detect in the 20 % of ears, demonstrating a broad band pattern, a broad band stimulus may not be ideal for clinical or screening purposes. Rather a frequency specific stimuli such as the relatively long tone burst may be necessary to obtain the highest possible incidence in normal ears (Probst et al., 1986).

Lot of discrepancies are seen among these studies which needs further investigations for us to satisfy the requirement for clinical application as a cochlear function test. Thus the present study aims at measuring the TEOAEs using clicks and tone bursts in normal and pathological ears.

Aims of the Study :

1. To compare the TEOAE responses [echo/signal to noise ratio] for clicks and tone bursts in normal hearing subjects and in individual with hearing impairment
2. To find out the correlation between puretone thresholds and cliks / tone bursts evoked otoacoustic emissions.
3. To identify the pattern and degree of hearing loss using clicks and tone burst evoked otoacoustic emissions in pathological cases.

REVIEW OF LITERATURE

Evoked otoacoustic emissions (OAEs) discovered by Kemp (1978) are acoustic phenomena regarded as inner ear origin and therefore are expected to be applied as an objective hearing test. Kemp et al. (1988) described that acoustic cochleography detected the presence of hearing loss but hardly quantified hearing loss. Nevertheless there is still need for its clinical application because the possibility of applying it as noninvasive objective test exists. To date, several studies for this purpose (Rutten, 1980 ; Robinette, 1992 ; Johnsen, Bagi & Elberling, 1983 ; Elberling et al.,1985 ; Probst, Lonsbury-Martin & coats, 1987 ; Tanaka, 1988 ; Bonfils, & Uziel, 1989 ; Stover & Norton, 1994 ; Fuse et al., 1994) have been attempted.

The various studies are reviewed under the following headings:

i. Relation between TEOAE reproducibility and hearing status.

ii. Comparison of clicks and tone burst evoked emissions.

iii. Correlation between puretone audiogram and TEOAE responses.

iv. Magnitude of hearing loss.

1. Relation between TEOAE reproducibility and hearing status:

There are two distinct situations in which the association of TEOAEs and hearing is straight forward. The case in which TEOAEs are present in 99 % of cases (Normal hearing) and cases in which TEOAEs are absent (Pathology in the ear). This basic dichotomy provides the basis for using TEOAEs in the identification of hearing loss in screening programs. For such purposes over all parameters such as percentage of reproducibility, response level or a combination of measures is calculated from the TEOAE and used to determine the presence or absence of hearing loss. The response is present only when the whole reproducibility score is 50 % or greater, and values less than 50 % is associated with hearing loss (Kemp et al.,1986).

In another study by Dijk and Wit (1987), wave reproducibility and response power to the noise power were used as criteria to decide whether a click evoked response is actually an emission. The measured emission was called an OAE, if the emission power was 3 dB above noise power and a wave form correlation better than 70 %. Eighty five out of two hundred and ten normal hearing ears had cochlear emissions, when 3dBSNR was used as a criteria. Also, 97 % of adults and 95 % of neonates had EOAE, when the criterion applied was 70 % reproducibility studied by Dolhen et al.(1991) in seventy one and thirty nine normal hearing adult and neonate ears respectively.

Whitehead et al.(1993) reported results from one hundred and forty nine normal hearing ears and one hundred and forty two ears with high frequency sensory neural hearing loss with atleast a portion of the puretone threshold better than 25 dBHL. 50 % reproducibility was able to differentiate ears with hearing loss from those without hearing loss.

Study by Welzl-Muller & Stephan, (1994) in five hundred and twenty five ears (age 3-11 years) indicated that in most of their absent TEOAEs the response level was about 7 dB and in most of the present TEQAEs it was above this leveL Reproducibility of more than 60 % was mainly observed in present TEOAEs.

Herer et al., 1996 studied two hundred and sixty children and adults and found a very high efficiency scores for response reproducibility in the region of 2000 Hz (using 50 % reproducibility criterion) and suggested that the clinicians can have greater confidence in their ability to identify presence of hearing loss between 250 to 4000 Hz using mis measure.

2. Comparison of Clicks and Tone bursts Evoked Emissions :

Most research on TEOAEs has been performed using click stimuli. Clicks have energy over a broad range of frequencies and generally the evoked OAE (CEOAEs) is broad band as well (Kemp et al., 1990). It is assumed that a large extent of the cochlea can be tested simultaneously by using click stimuli. This assumption is based on the fact that CEOAEs exhibit "Frequency dispersion", high frequency energy of CEOAEs emerging at short latencies followed by lower frequency emerging at lower latencies (Kemp, 1978).

TEOAEs can also be evoked using tone bursts (TBOAEs) which have narrower bandwidth and energy concentrated around the center frequency of the tone burst Fourier analysis of TBOAEs indicate that their spectral composition is similar to mat of evoking tone burst (Norton & Neely, 1987 ; Stover & Norton, 1993). To assess broad areas of the cochlea, tone bursts with varying center frequencies must be presented.

Kemp in 1978 said that responses to low intensity tonal stimuli at 800 Hz, 1100 Hz and 1800 Hz contained significant energy at the stimulus frequencies.

TBOAEs evoked by tone bursts with multiple cycles were essentially the sum of single cycle TBOAEs (Zwicker, 1983).

Elberling et al. (1985) studied five normal ears using 2 ms tone burst at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz at 60 dB SPL. There were preferred response frequencies. The dominance of which is some what dependent on the stimulus frequency, where as the frequency of individual peaks is independent of acoustic input

Probst et al., 1986 reported a very strong correlation between the evoking stimulus spectra and emission spectra for 16 cycles tone burst at 500 Hz, 1000 Hz, 3000 Hz, and 5000 Hz in twenty eight normal ears. Not all ears responded for all stimuli but when there were responses, their spectra closely resemble those of the evoking stimuli. The 1500 Hz tone burst was the only stimulus to evoke response from all ears and this was attributed to the increased sensitivity of both their recording system and the middle ear transfer function in mis frequency region.

Evoked and spontaneous emissions were measured by Probst et al. (1986) in a group of fourteen normal hearing subjects using clicks and tone bursts at frequencies 500 Hz, 1000 Hz, 1500 Hz and 3000 Hz. The 500 Hz tone burst evoked emissions in only 10 (36 %) ears, the 1500 Hz tone burst in all ears and the remaining stimuli in 80 % of the ears. Tone burst emissions were often prominent man CEOAE and at the frequencies of SOAE, prominent peaks in both clicks and tone bursts evoked otoacoustic emissions were present They concluded that click evoked OAEs were difficult to detect in 20 % of ears demonstrating a broad band pattern, a broad band stimulus may not be ideal for clinical or screening purposes. Rather, a frequency specific stimuli such as the relatively long tone burst may be necessary to obtain the highest possible EOAE incidence in normal ears.

Similar to this, Norton & Neely, (1987) in their study on seven normal hearing young adult females with tone bursts of center frequencies 500 Hz, 750 Hz, 1000 Hz, 1500 Hz and 2000 Hz with duration's 8 ms, 5.6 ms, 4 ms, 4.2 ms and 4 ms respectively found that the spectral characteristics of EOAEs in response to tone burst stimuli are primarily determined by the spectral characteristics of the evoking stimuli Emission spectra change in an orderly and consistent manner as a function of stimulus spectrum suggesting that emissions differing in spectra are generated at different places along the cochlear partition.

TBOAEs evoked by 1000 Hz and 1500 Hz tone burst had higher levels than those evoked by tone burst having center frequencies of 2000 Hz and 3000 Hz (Norton, 1993). Their study also showed that if the subject with hearing loss have TBOAEs and CEOAEs at frequencies where hearing is normal, the input / output functions were similar to those individuals having normal hearing across the audiometric range.

The input / output functions for tone bursts from 1000 Hz and 3000 Hz showed saturation starting at approximately 50 dB SPL (Stover & Norton, 1993).

Click evoked and tone burst evoked otoacoustic emissions input / output functions and group latencies for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz were studied by Prieve et al., 1996 in normal hearing and hearing impaired to determine the extent to which these two types of TEOAEs were similar. The clicks and tone bursts evoked otoacoustic emission input / output functions were essentially identical in regions of normal hearing in hearing impaired subjects. The TEOAE amplitude is highest in the 1000 Hz band which was also reported by Stover & Norton, 1993.

Harrison & Norton (1999) used clicks and 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz tone bursts to find out the characteristics of TEOAEs (signal to noise ratio, amplitude and reproducibility) in forty four children with sensory neural hearing loss, mixed hearing loss and normal hearing. The click responses filtered in to half octave bands centered at 2000 Hz and 4000 Hz were comparable with those for the broad band click. The 2000 Hz band was superior for identification of hearing loss greater than or equal to 20 dBHL for an 80 dBpe SPL click, and greater than or equal to 30 dBHL for an 86 dBpe SPL click. Results for tone bursts, centered at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz presented at 80 dBpe SPL, were similar to results of the filtered click bands. The accuracy for identifying hearing loss increased with increasing center frequencies. The 2000 Hz and 4000 Hz tone bursts provided the best separation between normal hearing and hearing impaired ears with 4000 Hz being slightly better.

For a given pSPL, the tone bursts have greater spectral density due to the smaller bandwidth of the stimulus. Therefore in situations where there are peak limitations of earphones, a tone burst may be the stimulus of choice. For frequencies contaminated by excessive noise eg. 500 Hz and 1000 Hz, tone burst may be superior to clicks because the evoked TEOAEs will have a greater amplitude.

3. Correlation between puretone radiogram and TEOAE responses :

One application that has been emphasized is the determination of the relation of OAE test results to audiometric findings. Results have been evaluated in terms of their potential for screening or the predicting hearing levels by frequency.

Avan et al.(1991) investigated the relationship between the amplitude and threshold of TEOAE and the audiogram and found that these parameters (threshold and amplitude) donot show frequency specificity.

In 1991, Collet et al. calculated correlations between spectrum analysis of evoked OAEs and hearing loss in one hundred and fifty patients with pure sensory neural hearing loss. Significant correlations were found and they concluded that greater the high frequency spectral components of the EOAE, the better the high frequency hearing and was difficult to establish audiogram knowing only the spectrum analysis of EOAEs.

Similarly Fuse et al.(1994) studied the amplitude power spectrum of TEOAE and the audiogram on one hundred and fifty-four patients with SNHL and forty two normal hearing adults. There was no significant correlation between the audiogram and response spectrum of the TEOAE. However, it may be difficult to derive an audiogram based on the response spectrum of TEOAE transversely.

Hussain et al. (1998) studied TEOAE responses in four hundred and fifty-two ears of both normal and hearing impaired patients. TEOAE amplitudes, signal to noise ratios (SNRs) analyzed in to octave bands centered at lOOOHz, 2000Hz and 4000Hz were compared with puretone threshold at the same frequencies. TEOAEs accurately identified auditory status at 2000Hz and 4000Hz but were less accurate at lOOOHz. TEOAE SNR showed better test performance than did TEOAE amplitude.

4. Magnitude of hearing loss :

Parameters of TEOAEs are influenced strongly by both auditory threshold levels and the frequency distribution of normal versus abnormal hearing in an individual ear. Understanding the nature of these influences is fundamental to sound interpretation of TEOAEs either for screening or for the prediction of hearing level by frequency.

The outcome of majority of investigations have been designed to determine the cut off levels of hearing that can be identified with TEOAEs. The cases in which overall hearing is better than 20dBHL, TEOAEs are present in 99% of ears and cases of sensory neural hearing loss, greater than 40dBHL with no complicating etiological factors, TEOAEs are always absent. This basic dichotomy provides the basis for using TEOAEs in the identification of hearing loss in screening programs. When hearing threshold levels were less (i.e poorer) than

20dBHL, TEOAE responses decreased sharply, and there was no direct correspondence between the degree of changes in any TEOAE parameter and the magnitude of hearing loss.

TEOAE measurements have excellent sensitivity in identifying hearing loss greater than 20dBHL and have been reported to have perfect sensitivity when used to identifying a puretone average greater man 40dBHL in children.

Rutten (1980) studied twenty-nine ears of eighteen subjects with no conductive pathology and found that emissions will be observed if the hearing loss at the frequency of the emissions, less man 15dBHL.

The ears with losses upto 20dBHL can produce cochlear emissions where as no emissions could be measured when greater losses were present (Johnson & Elberling,1982; Johnson et al., 1983; Ruggero et al., 1983)

About 80-90 % of normally hearing ears produce OAEs but these emissions can seldom be recorded from persons with hearing loss in excess of 20-30dBHL(Cope & Lutman,1988).

Otoacoustic emissions can be measured in almost all normally hearing individuals of all ages and OAEs are absent or reduced in the presence of hearing impairment (Kemp, Ryan & Bray, 1990).

TEOAES are frequently reduced in ears with minor sensory neural hearing impairment and generally absent in ears with SNHL exceeding 30dBHL(Kemp,1978).

Contrasting to this Kemp et al. (1986) recorded click evoked OAEs in eighty eight ears with SNHL and reported that only five ears with a mean hearing loss exceeding 15dBHL generated an emission above the mean noise level obtained. About 5% of the subjects with a mean hearing threshold better than 15dBHL failed to produce a CEOAE above the mean noise level obtained.

Bertoli & Probst,(1997) studied two hundred and one subject aged 60years, with sensory neural hearing loss, and found a prevalence of TEOAEs in a typical clinical population of elderly subjects of 60%, when PTA was within 30dBHL. No emissions could be detected if PTA exceeded 30dBHL. If TEOAEs were present, response levels decreased as hearing threshold levels increased but there was no. influence of age alone. The tone burst results do not differ qualitatively from those found in young adults. They concluded that evaluation of TEOAE is of little clinical value in the routine evaluation of elderly persons with mild to moderate hearing loss.

CEOAEs were detected in thirty-four out of thirty five SNHL ears with a subjective click threshold less than 55dBSPL(25 dBnHL) by Probst et al. (1987). None of nine ears with SNHL and a subjective click threshold above this level demonstrated CEOAE.

Study by Stevens (1988) in thirty one ears with hearing impairment and thirty six ears with normal hearing showed that no subject with a hearing threshold at or above 18dBnHL for the click stimuli produced emissions. 97.4% of ears produced emissions if the threshold was at 13dBnHL or lower. If the mean of the puretone audiogram was used, the division was at 20dBHL, although two ears produced emissions with mean threshold of 23.8 and 33.8 dBHL and they said mat the test will only differentiate between normal and hearing impairment and that cannot be used to estimate psycho-acoustical thresholds.

Collet et al. (1989) recorded CEOAE in one hundred and forty eight ears of seventy six subjects with SNHL and found statistically, a highly significant correlation between CEOAE threshold and hearing loss at l000Hz. CEOAEs were never found when hearing loss at l000Hz exceeding 40dBHL and when the mean hearing loss at 500Hz, l000Hz, 2000Hz, and 4000Hz exceeded 45dBHL.

No CEOAEs were obtained from ears with significant high frequency losses with preservation of hearing at lOOOHz (Bonfilis & Uziel, 1989).Another study by Johnson, Parbo & Elberiing (1993) on mild to moderate, flat, steeply slopping hearing showed that no emission could be obtained from ears with a flat cochlear hearing impairment exceeding 40dBHL in the mid frequency region, but than emission could be recorded in ears with significant high frequency loss. Even a severe cochlear hearing loss at 4000Hz and 8000Hz seems to be of no significance for presence of CEOAE.

However in the case of high frequency hearing loss, the threshold at l000Hz and 2000Hz appears to be crucial. No CEOAEs could be obtained from ears with a threshold exceeding 25dBHL at l000Hz and 60dBHL at 2000HZ.The audiometric limits for the generation of CEOAE in flat sensory neural losses were 30-40dBHL in the 1000-2000Hz region.

Thus the present study was aimed at probing into all the above mentioned perspectives.

METHODOLOGY

The present study aimed at comparing the click and tone burst evoked otoacoustic emissions in normals and pathological ears.

Subjects :

The subjects for the study consisted of 2 groups. Group I and Group II.

Group I consisted of 17 adult (34 ears) volunteers, aged 15-50 years (5 males and 12 females) who were students / staff of All India Institute of Speech and Hearing.

Group II consisted of 27 adult patients (44 ears) aged 15-50 years (13 males and 14 females) who were registered at All India Institute of Speech and Hearing for evaluation.

Selection Criteria :

The criteria based on which the subjects were selected are as follows :

Group I:

a) Puretone thresholds within 15 dBHL for the frequencies 500, 1000, 2000, 3000 and 4000 Hz.

b) Normal middle ear functioning as ascertained by using the immitance audiometer

c) No history of any otological or neurological problems were reported.

Group II :

a) Pure tone thresholds within 55 dBHL for the frequencies 500, 1000, 2000, 3000 and **4000** Hz., with the air bone gap less than 10 dBHL which included flat, sloping, rising, audiogram patterns.

b) Normal middle ear functioning as ascertained by using the immitance audiometer

c) No history of any symptoms related to middle ear.

Instrumentation :

The following equipments were used for the testing.

A. Pure tone Audiometer:

A two channel clinical audiometer (Grason Stadler 61 / Orbiter 822 with TDH 50 / TDH 39 earphone respectively and radioear B 71 bone conduction vibrator) was used to find out the pure tone thresholds. The audiometer was calibrated prior to the study according to the standards specified.

B. Immittance audiometer :

Immittance evaluation was carried out using Grason Stadler -33 middle ear analyzer. The immittance audiometer was calibrated prior to the study according to the standards specified by the manufacturer.

C. **Otoacoustic Emission Analyzer**:

Transient evoked otoacoustic emissions were measured using **ILO** 292 (Software version 5) in standard default operational mode. The stimuli were presented with a repetition rate of 80 Hz (12.5ms between stimuli). The filter setting was 500 - 6000 Hz. Two different stimulus was used, click and tone bursts and the range of stimulus levels were as follows :

i. 75.2 dBpeSPL to 95.5 dBpeSPL for clicks,

ii. 65.6 to 76.5 dBpe SPL for 1000 Hz tone burst

iii. 63.1 to 76.5 dBpe SPL for 2000 Hz tone burst

iv. 59.1 to 86.9 dBpe SPL for 3000 Hz tone burst

v. 59.6 to 87.6 dBpe SPL for 4000 Hz tone burst

Emissions were measured 2 ms after the stimulus presentation and the time window was 20 ms. The stimuli were presented in blocks of four where three stimuli of one polarity were added to a fourth stimulus of opposite polarity three times the amplitude so that the stimulus artifact was minimized. A suitable probe with appropriate ear tip was used. The responses were stored after completion of 260 averages.

Test Environment :

All the measurements were made in a quiet room. The subjects were seated in a comfortable chair with arm rests during testing. All the subjects were asked to sit in the same position till the completion of the test.

Test Procedure:

Initially all the subjects in both groups were screened in a verbal interview for a history of otological disease, noise exposure, ototoxic drug use, metabolic diseases associated with hearing loss and a family history of hearing impairment Pure tone audiometry was carried out for both Group I and Group II. The subjects with normal hearing were taken for Group I and subjects with minimal to moderate sensory neural hearing loss with various configurations were taken for Group II. All the subjects in Group I and Group II were tested for tympanograms and reflexes in both ears. The subjects who had 'A' type tympanograms with reflexes present in normals & absent / elevated in sensory neural hearing loss were taken for the TEOAE measurement. The probe calibration and stimulus calibration was done prior to the OAE measurement. The testing procedure was as follows :

1. The ILO 292, acoustic probe fitted with disposable, plastic tip was inserted in to the subjects/patients ear.

2. A standard click / tone burst stimuli was applied and the resultant sound in the ear canal was displayed as a waveform and spectrum so that the probe fit was checked and adjusted as seen in fig 1. Following mis, the test began.

3. The preset stimulus (either clicks / tonebursts at 1000, 2000, 3000, 4000 Hz) was repeatedly applied and the delayed sound field in the ear canal was captured, digitized and accumulated in the computer memory to enhance the detection of the small cochlear echo signals against the background noise. TEOAE responses were then filtered to specific bandwidths centered at 1000,2000, 3000,4000Hz and then displayed.

4. On termination of the test the accumulated response was displayed as a waveform on the computer screen and also as a frequency spectrum. The responses were automatically tested for signal validity by means of non-

linearity and reproducibility and an SNR of 3 dB or above (Dijk & Wit, 1987) was considered as a response. Clicks or tone bursts evoked emissions which were displayed in terms of SNR at different center frequencies were then taken for statistical analysis.

Statistical Analysis :

The data obtained for clicks and tone bursts were tabulated. The paired 't' test was used to compare the clicks and tone bursts evoked response amplitude (SNR) in both normal and pathological ears.

The Karl-Pearson's product moment rank order correlation was used to find out the correlation between pure tone thresholds and TEOAE responses.

The TEOAE responses obtained in a subject with normal hearing and in a subject with sensory neural hearing loss are shown in the Figures 2-5.

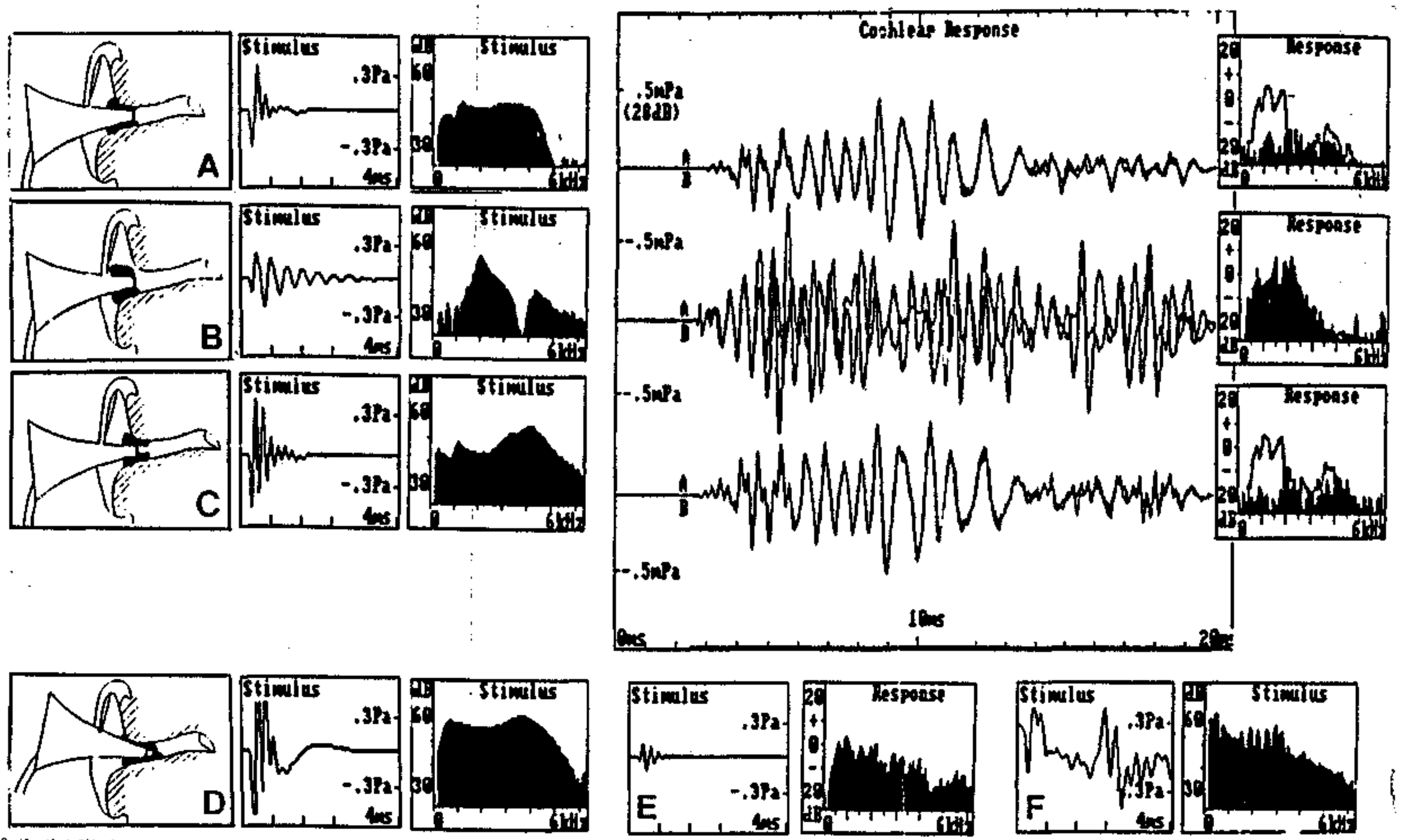

Fig 1 : Shows six different probe fitting conditions. (A) Acceptable fit ; (B) Leaky fit ; (C) Poor rubber fitting ; (D) Internal probe blockage ; (E) Probe fallen out of the ear ; (F) Good fitting, but high patient noise.

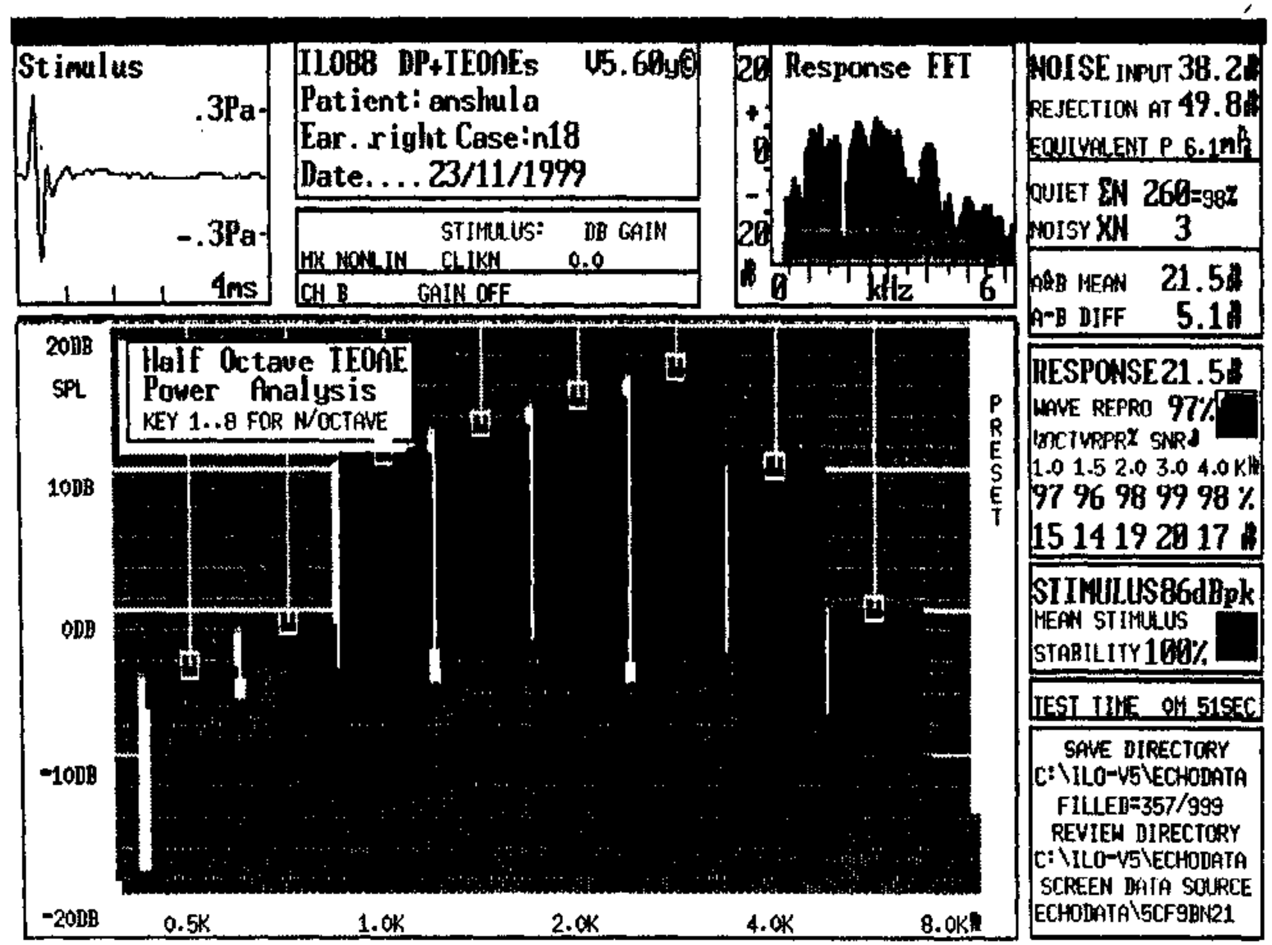

Fig 2.1: Shows click evoked response in a subject with normal hearing.

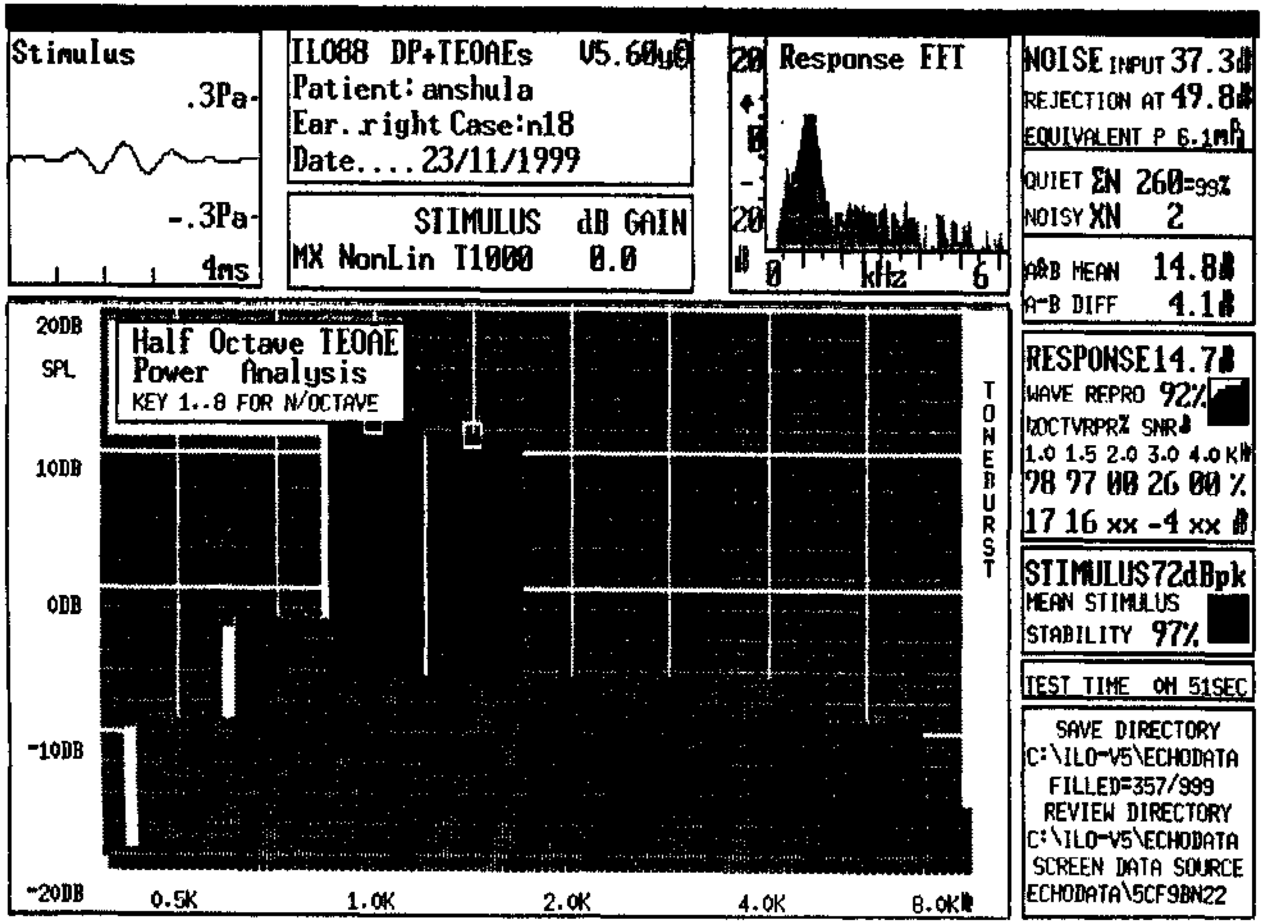

Fig 2.2 : Shows 1000 Hz tone burst evoked response in a subject with noramal hearing.

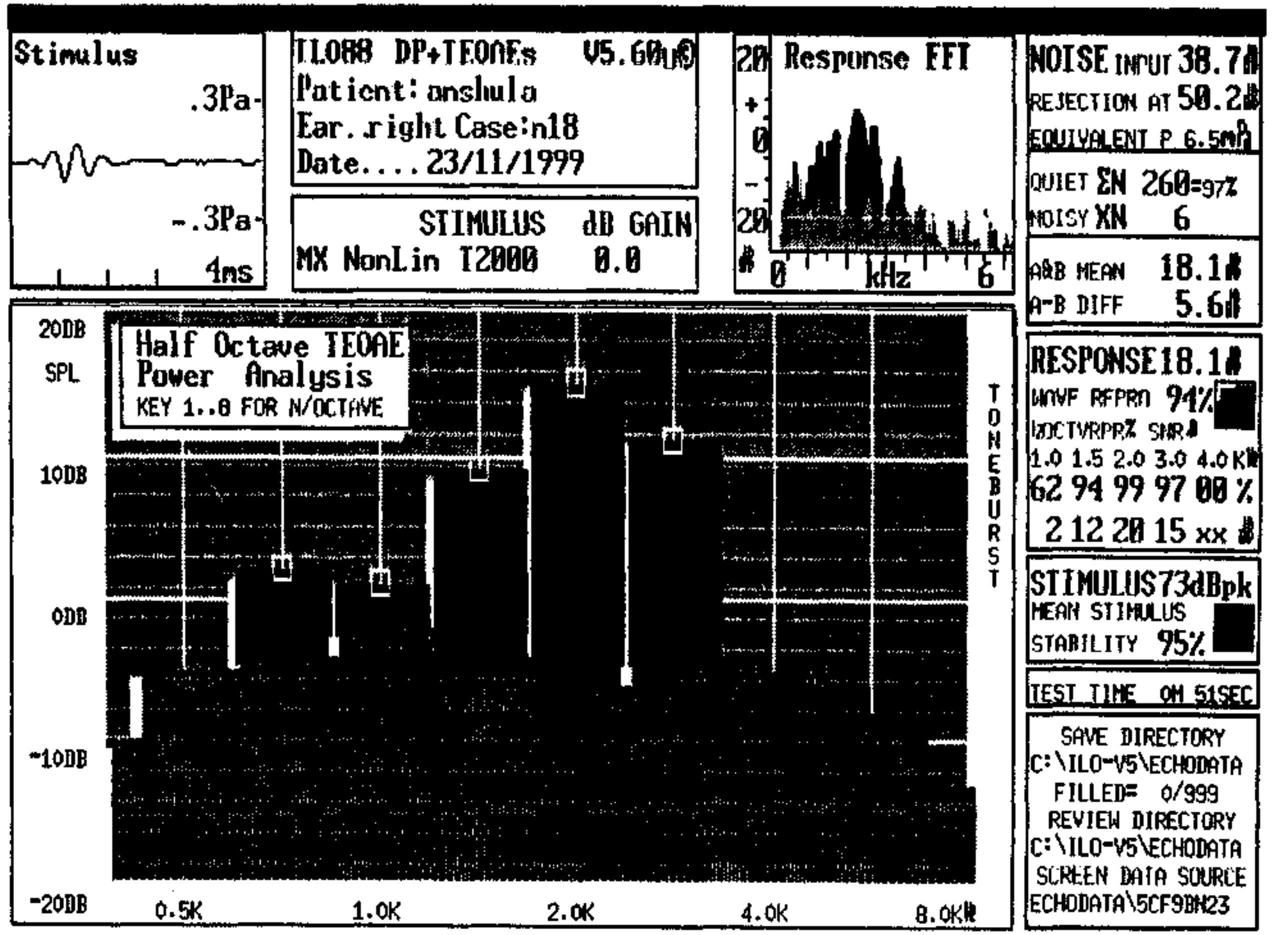

Fig 2.3 : Shows 2000 Hz tone burst evoked response in a subject with noramal hearing.

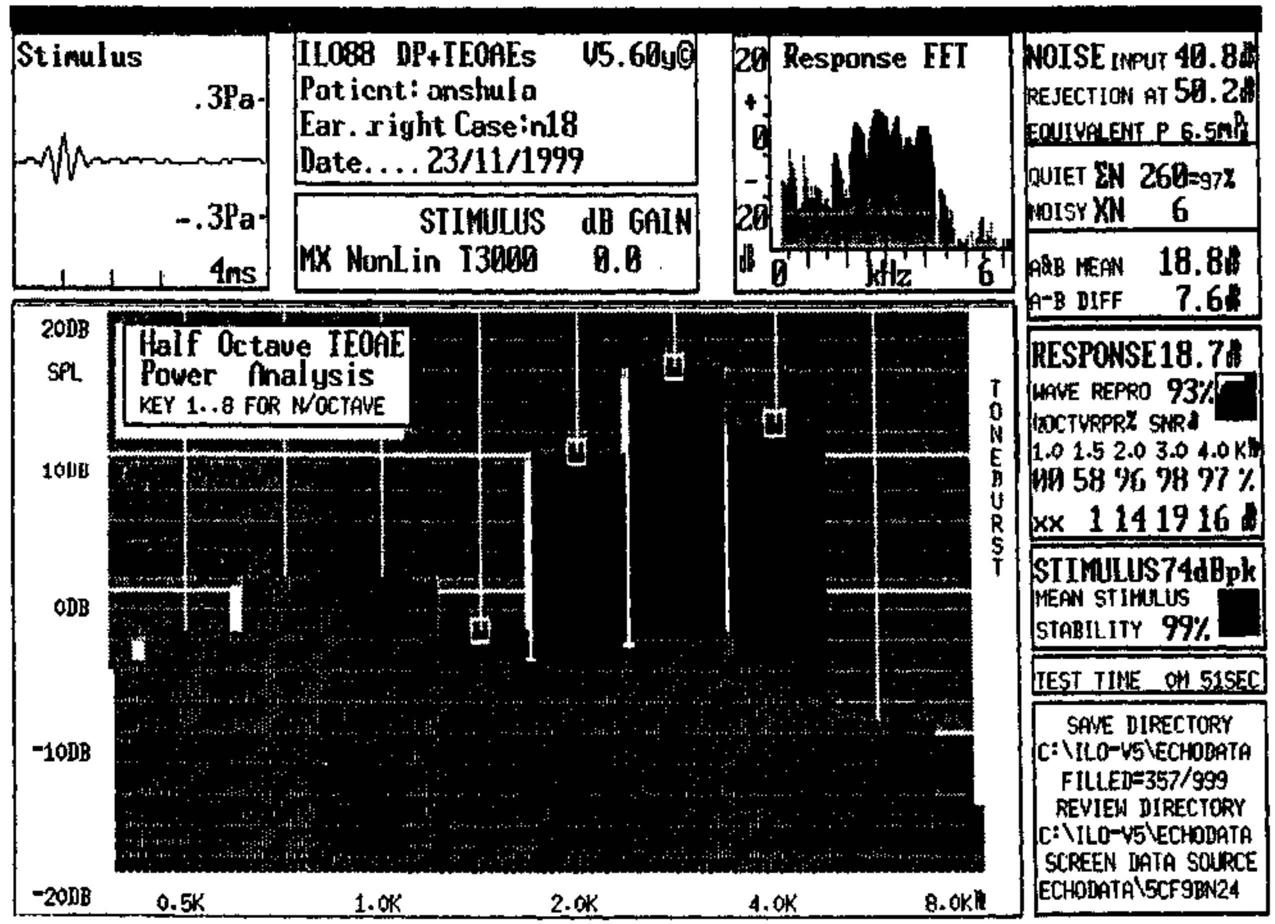

Fig 2.4 : Shows 3000 Hz tone burst evoked response in a subject with noramal hearing.

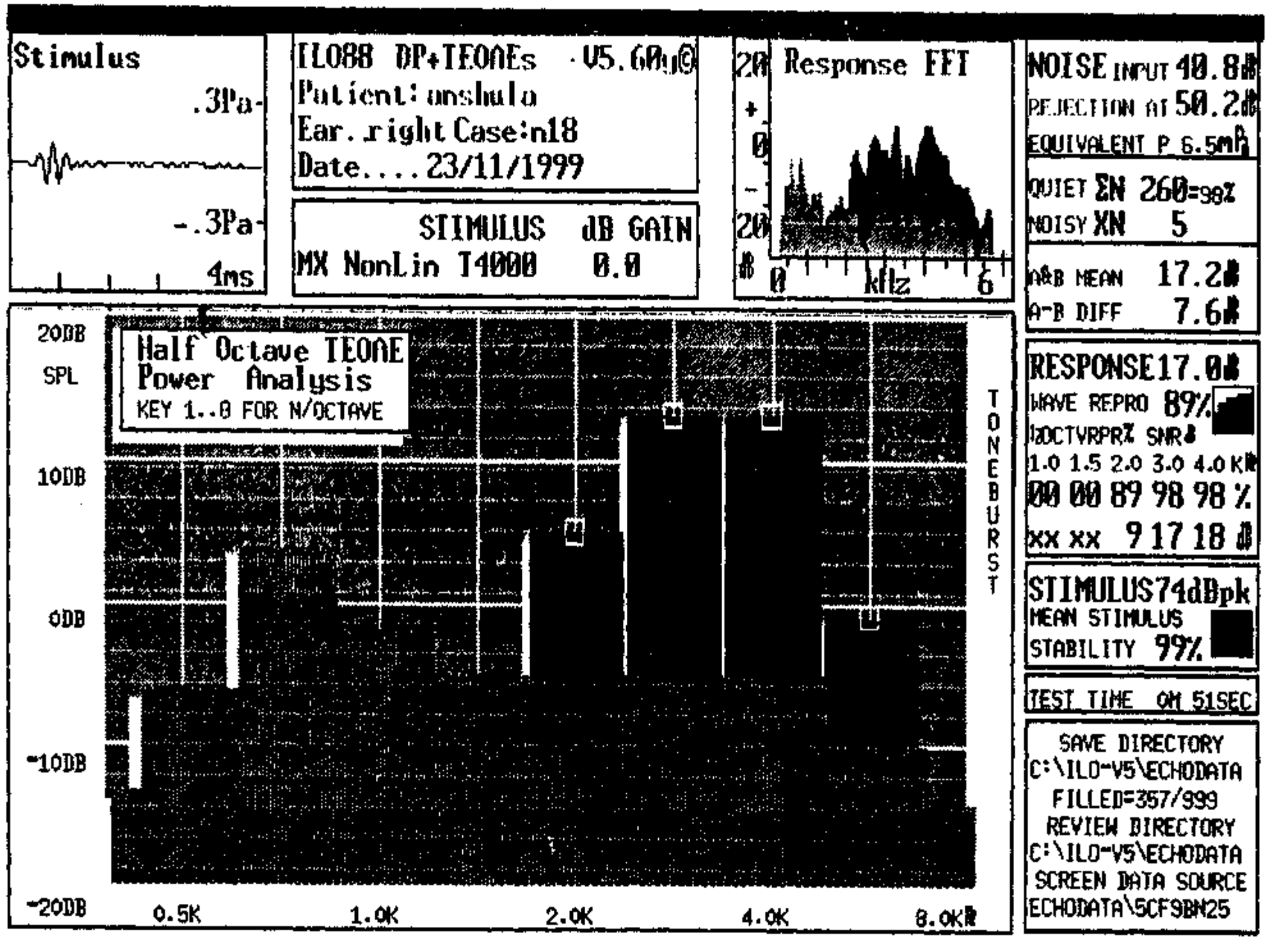

Fig 2.5 : Shows 4000 Hz tone burst evoked response in a subject with noramal hearing.

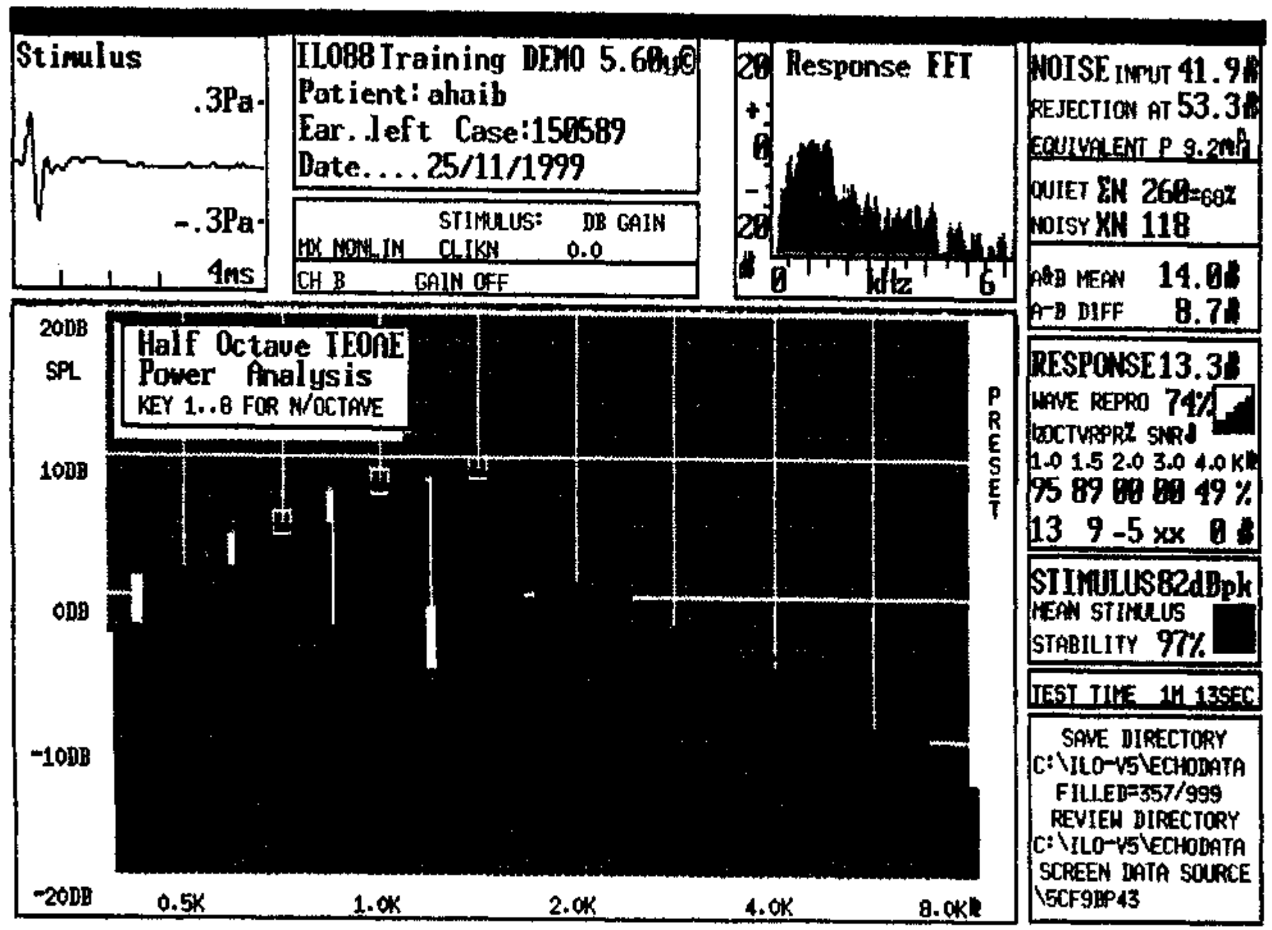

Fig 3.1 : Shows click evoked response in a case with minimal sensoryneual hearing loss.

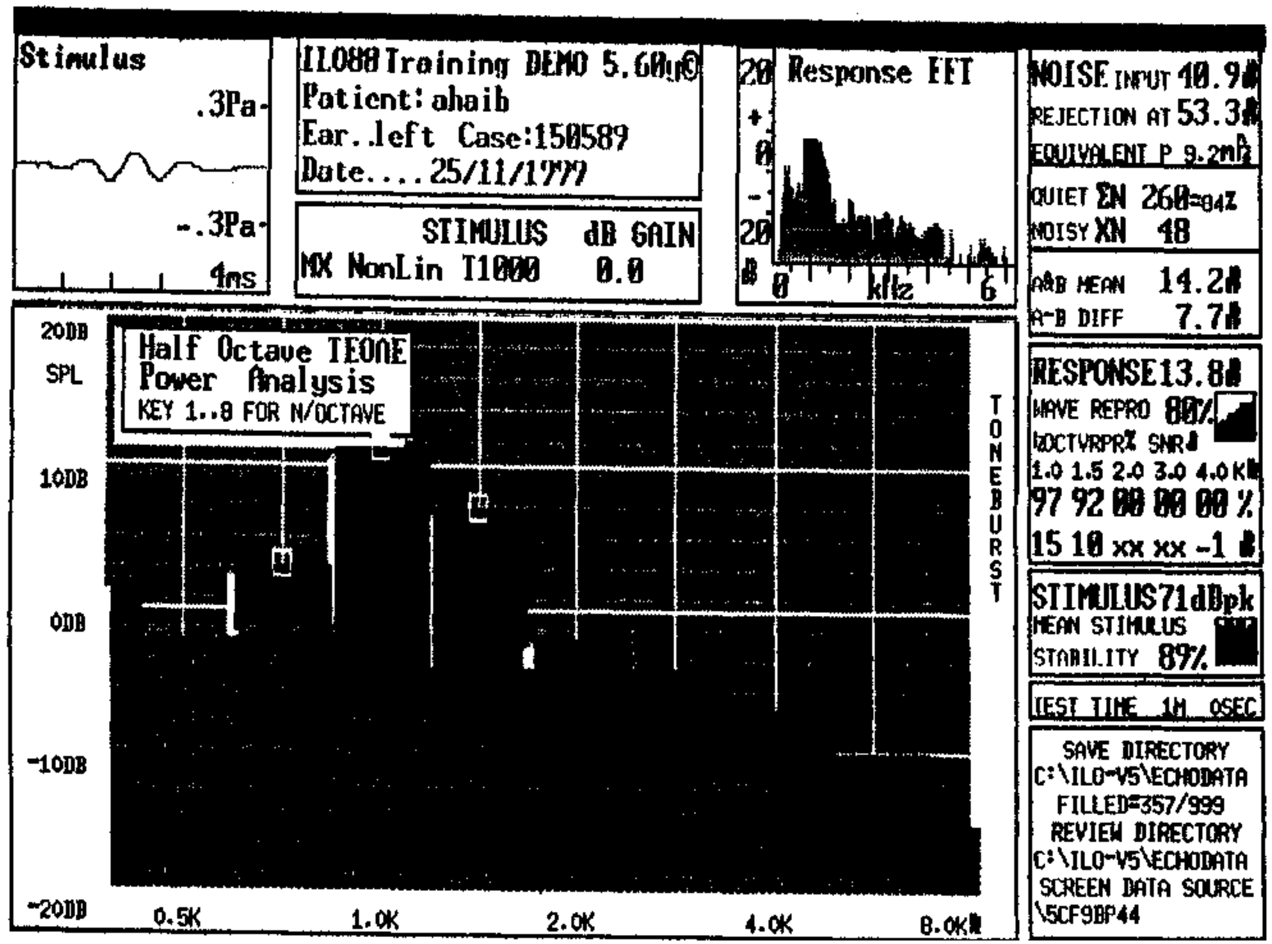

Fig 3.2 : Shows 1000 Hz tone burst evoked response in a case with minimal sensoryneural hearing loss.

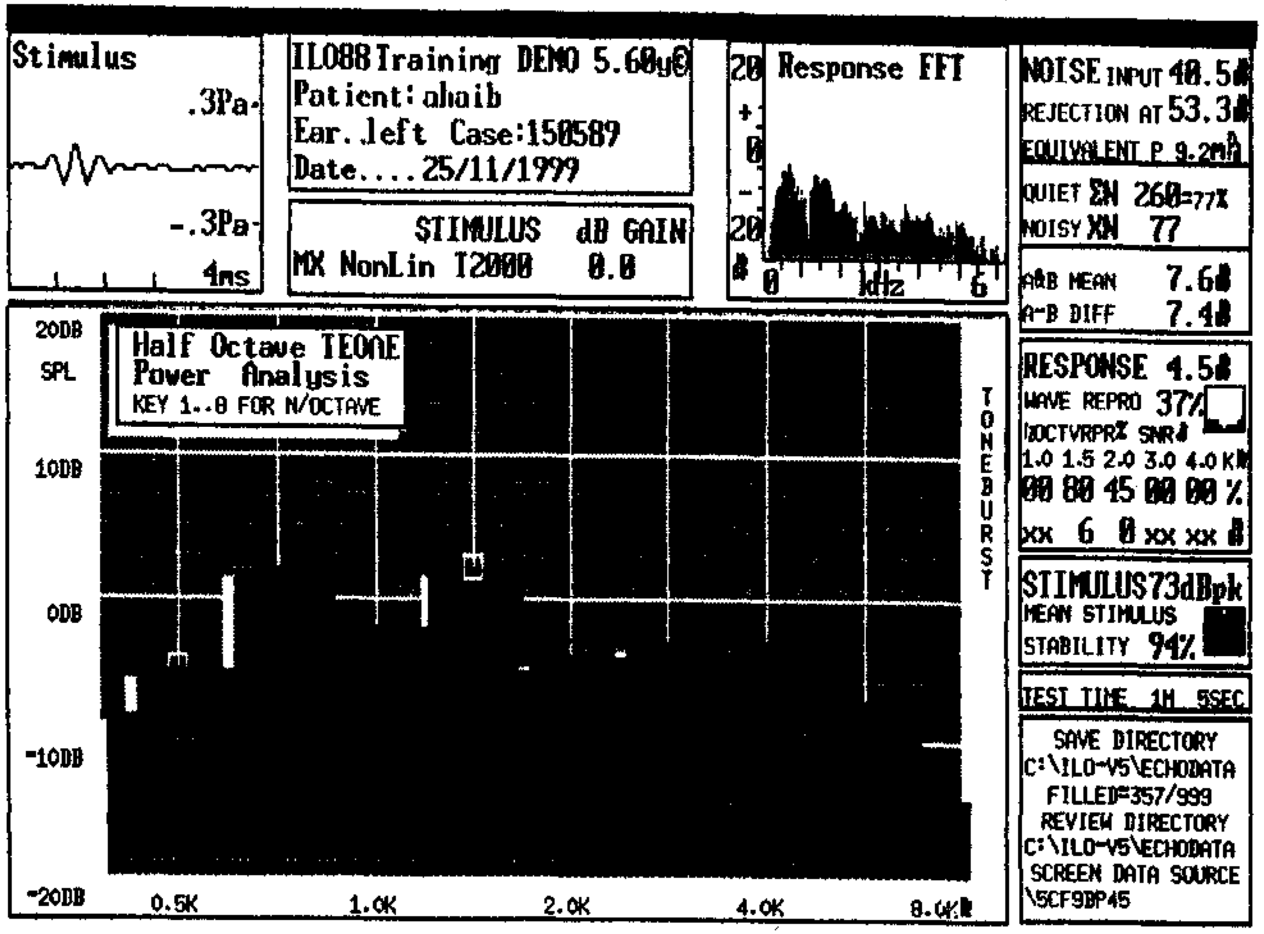

Fig 3.3 : Shows 2000 Hz tone burst evoked response in a case with minimal sensoryneural hearing loss.

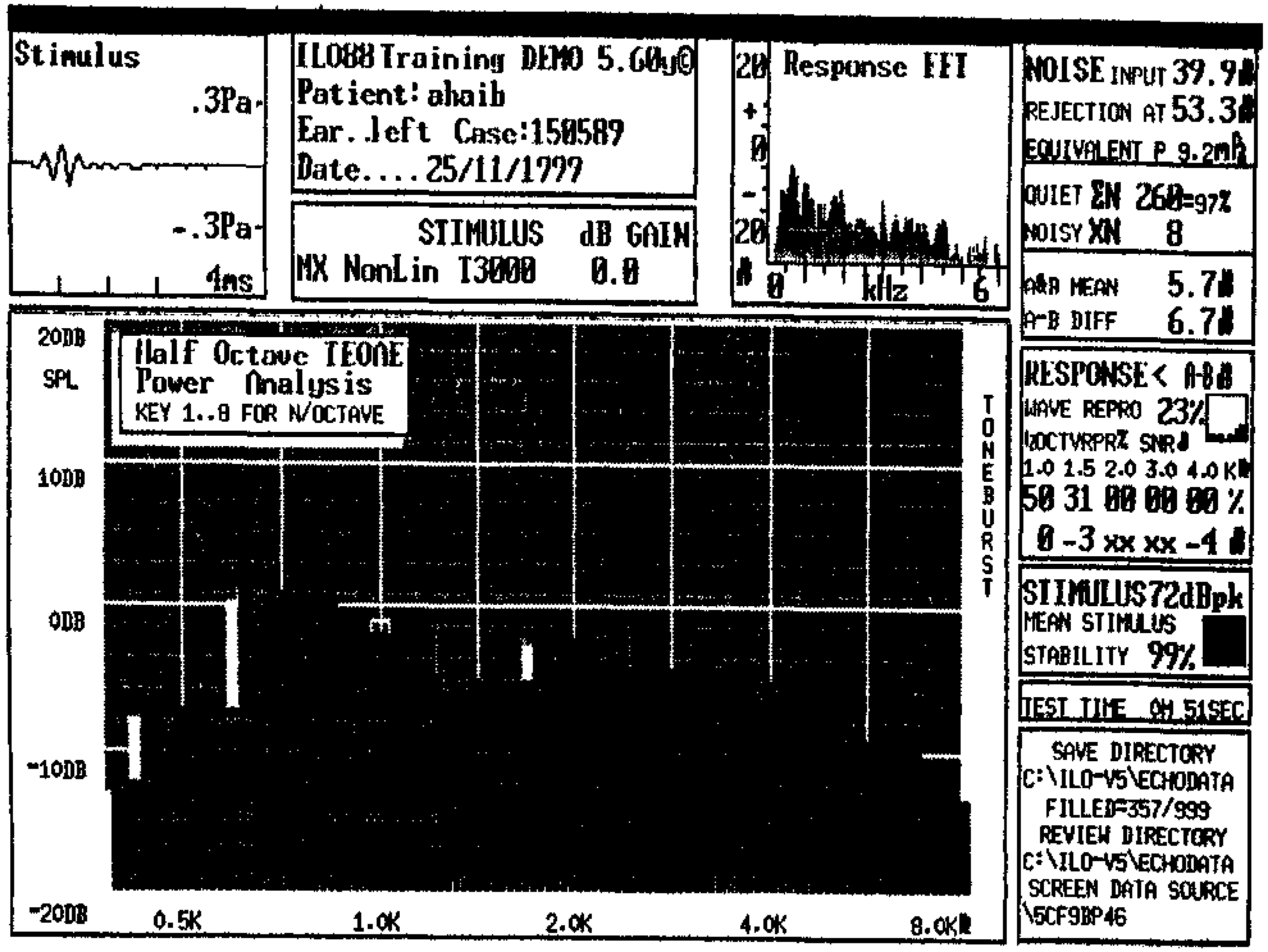

Fig 3.4 : Shows 3000 Hz tone burst evoked response in a case with minimal sensoryneural hearing loss.

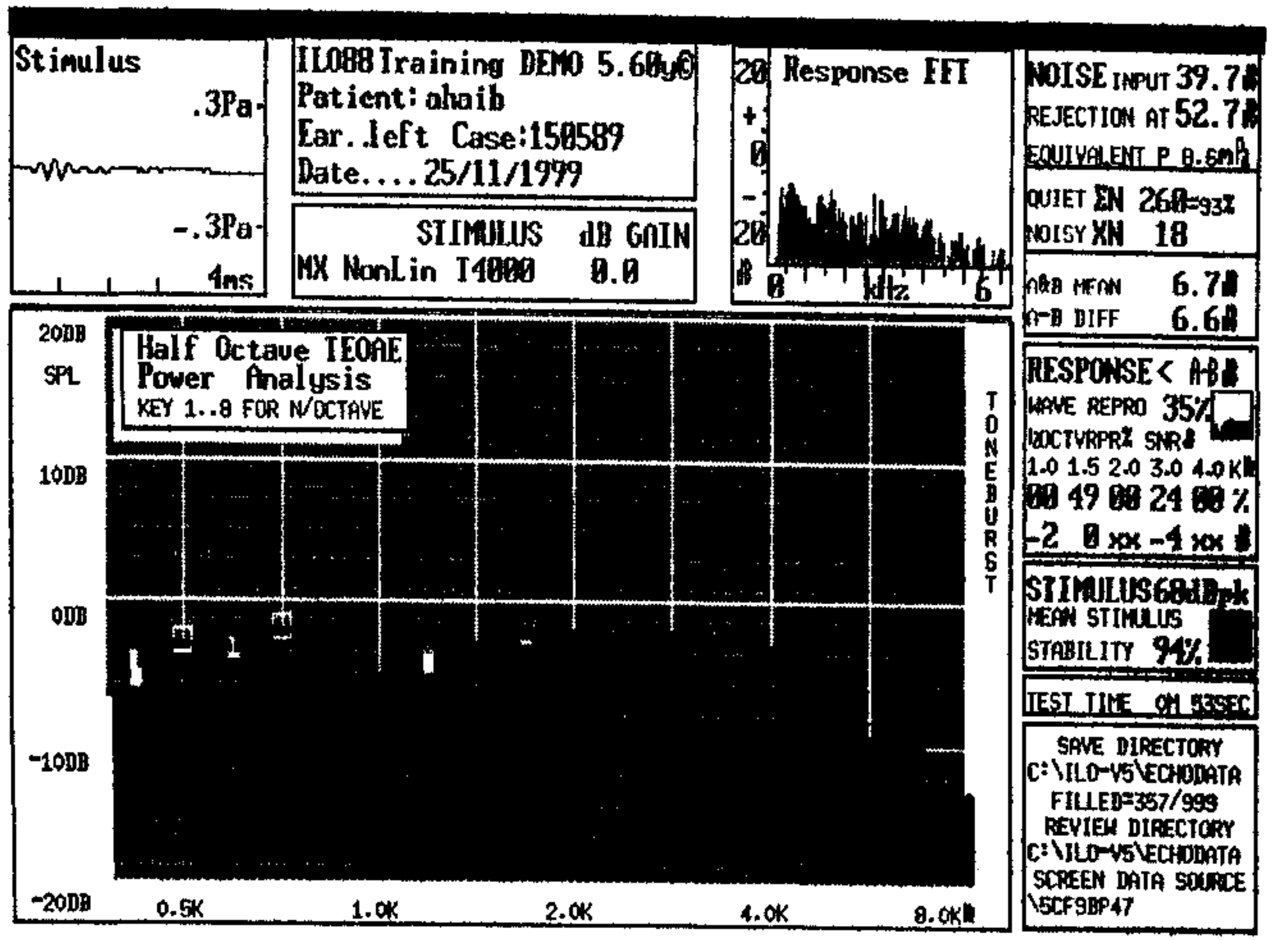

Fig 3.5 : Shows 4000 Hz tone burst evoked response in a case with minimal sensoryneural hearing loss.

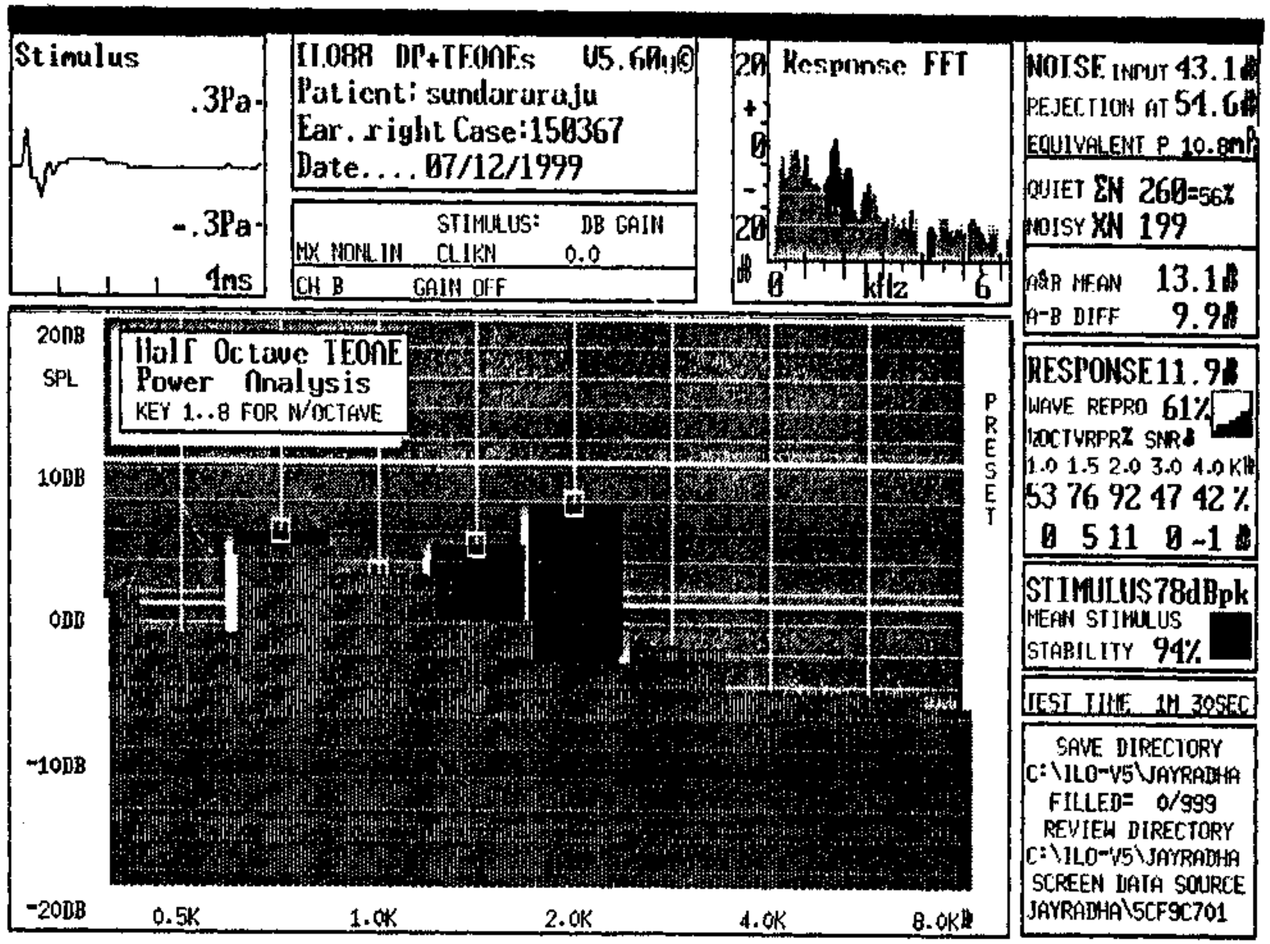

Fig 4.1: Shows click evoked response in a case with high frequency sloping sensoryneural hearing loss.

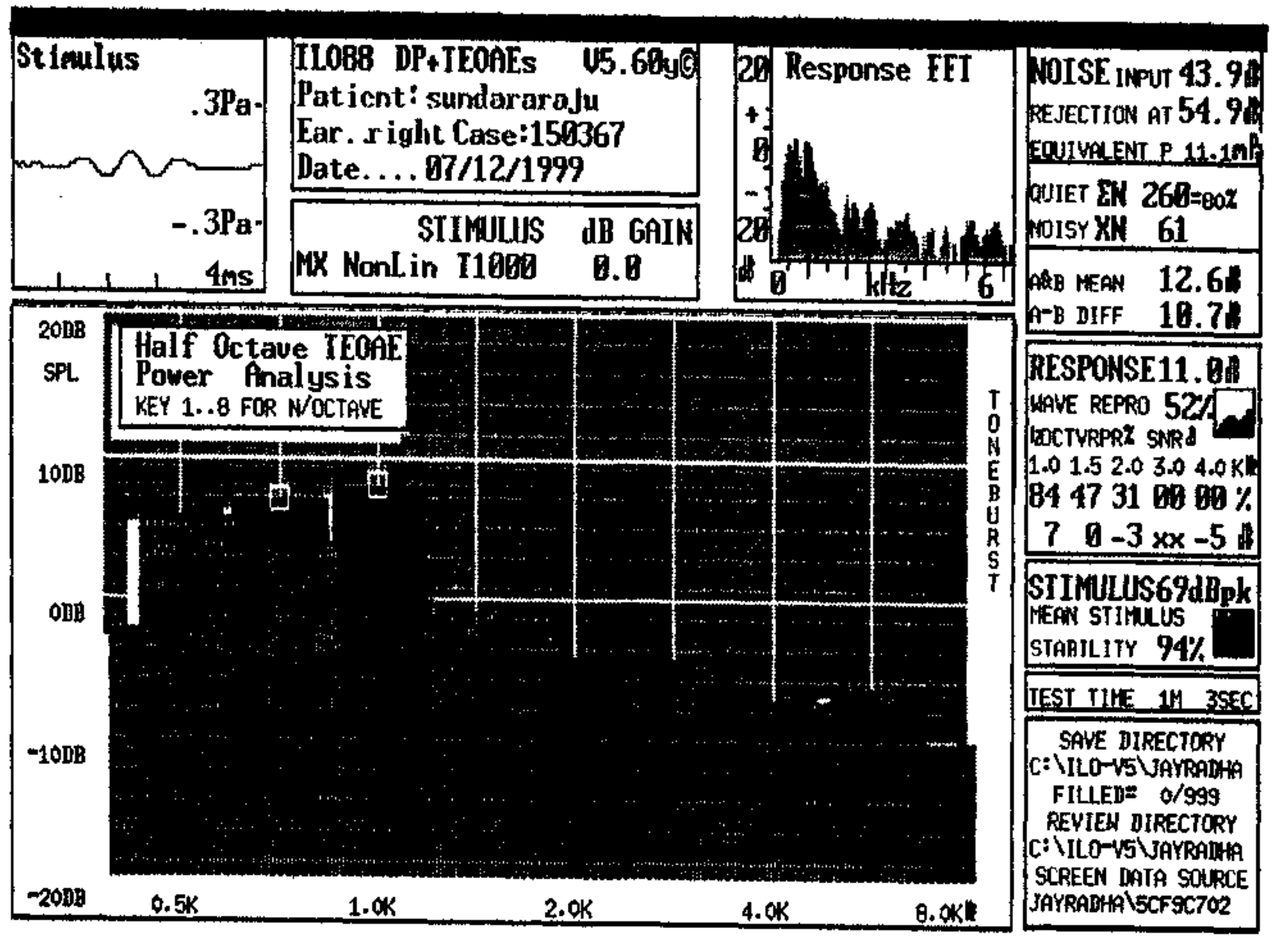

Fig 4.2 : Shows 1000 Hz tone burst evoked response in a case with high frequency sloping sensoryncural hearing loss.

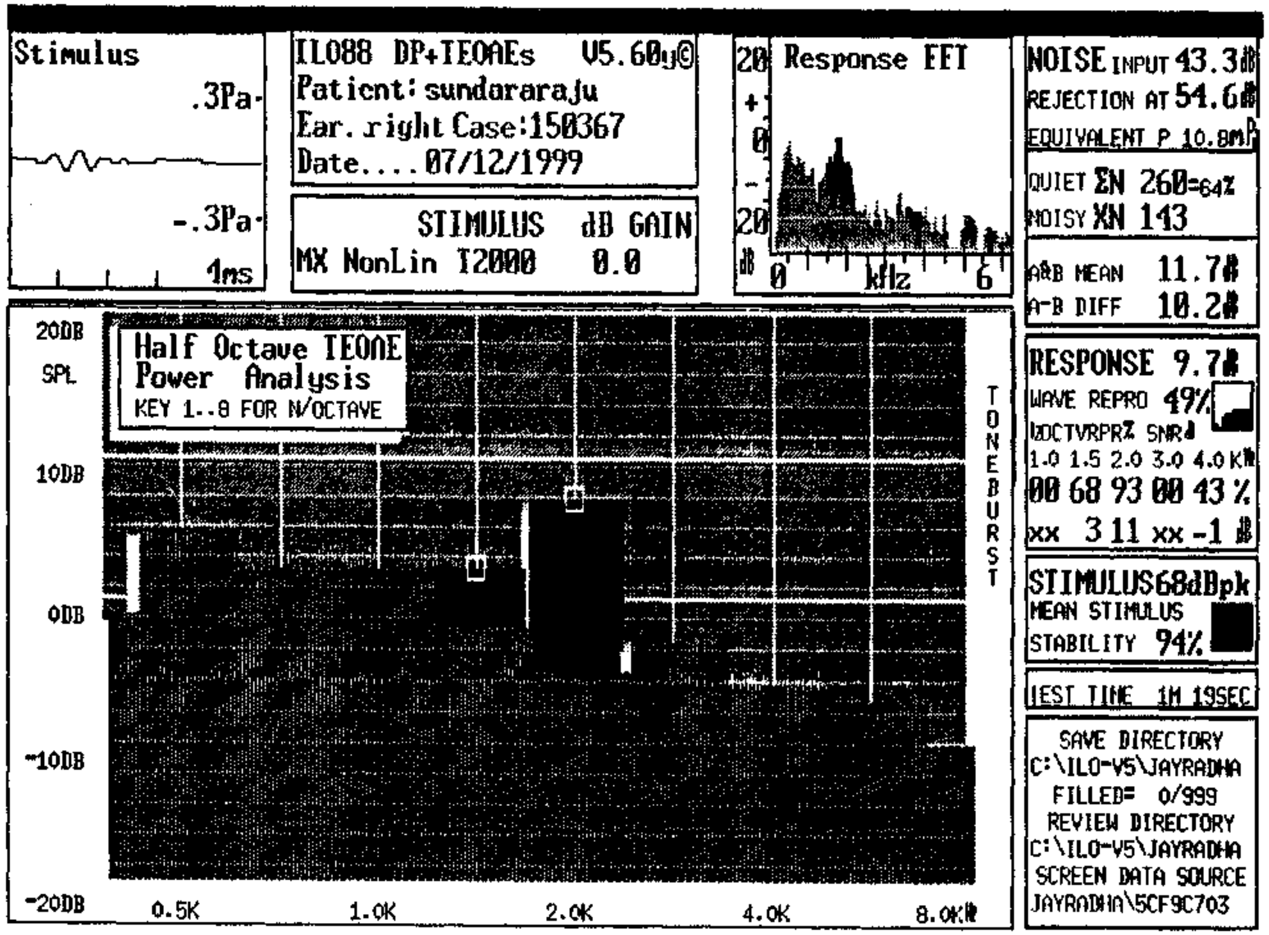

Fig 4.3 : Shows 2000 Hz tone burst evoked response in a case with high frequency sloping sensoryneural hearing loss.

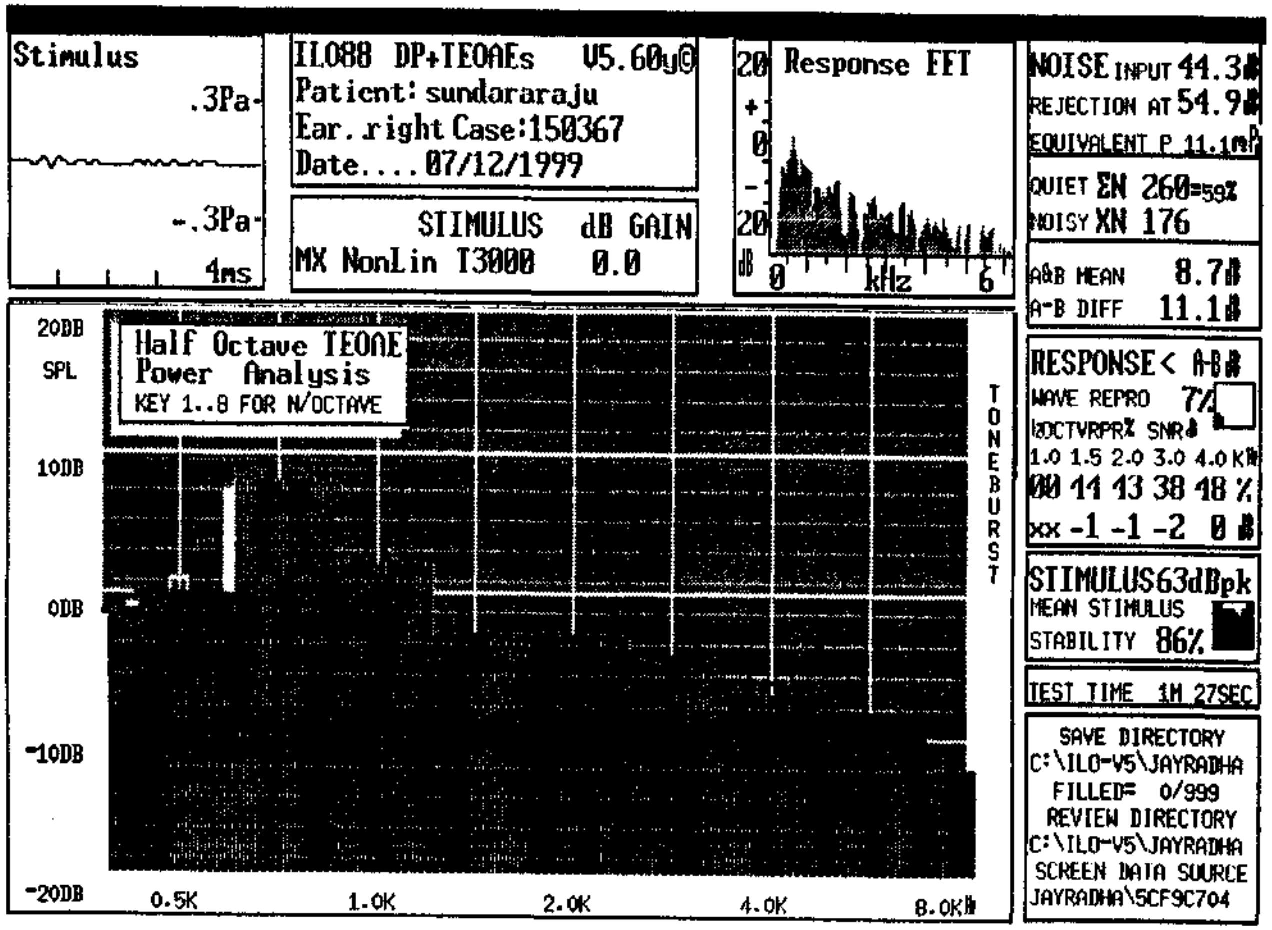

Fig 4.4 : Shows 3000 Hz tone burst evoked response in a case with high frequency sloping sensoryneural hearing loss.

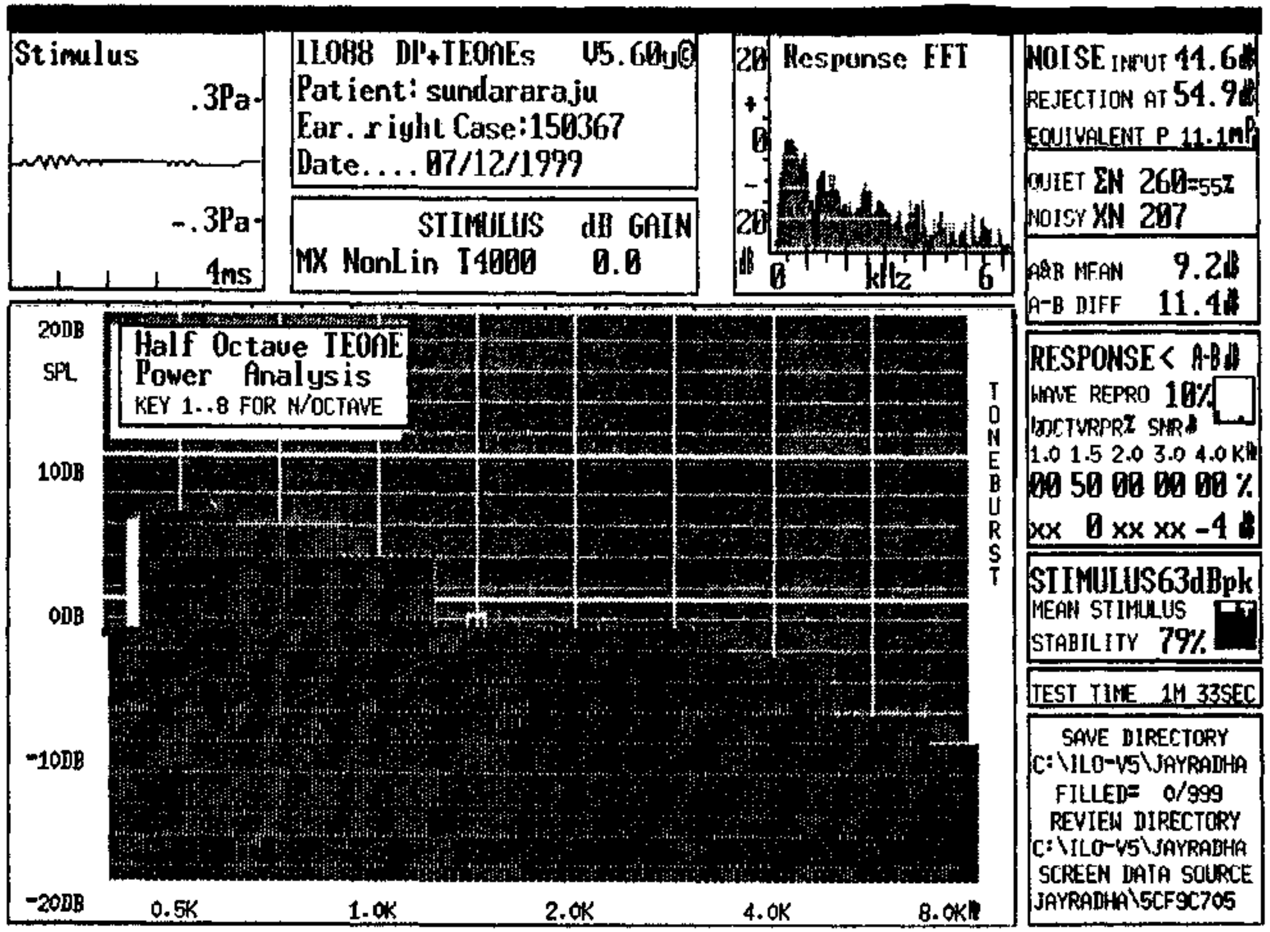

Fig 4.5 : Shows 4000 Hz tone burst evoked response in a case with high frequency sloping sensoryneural hearing loss.

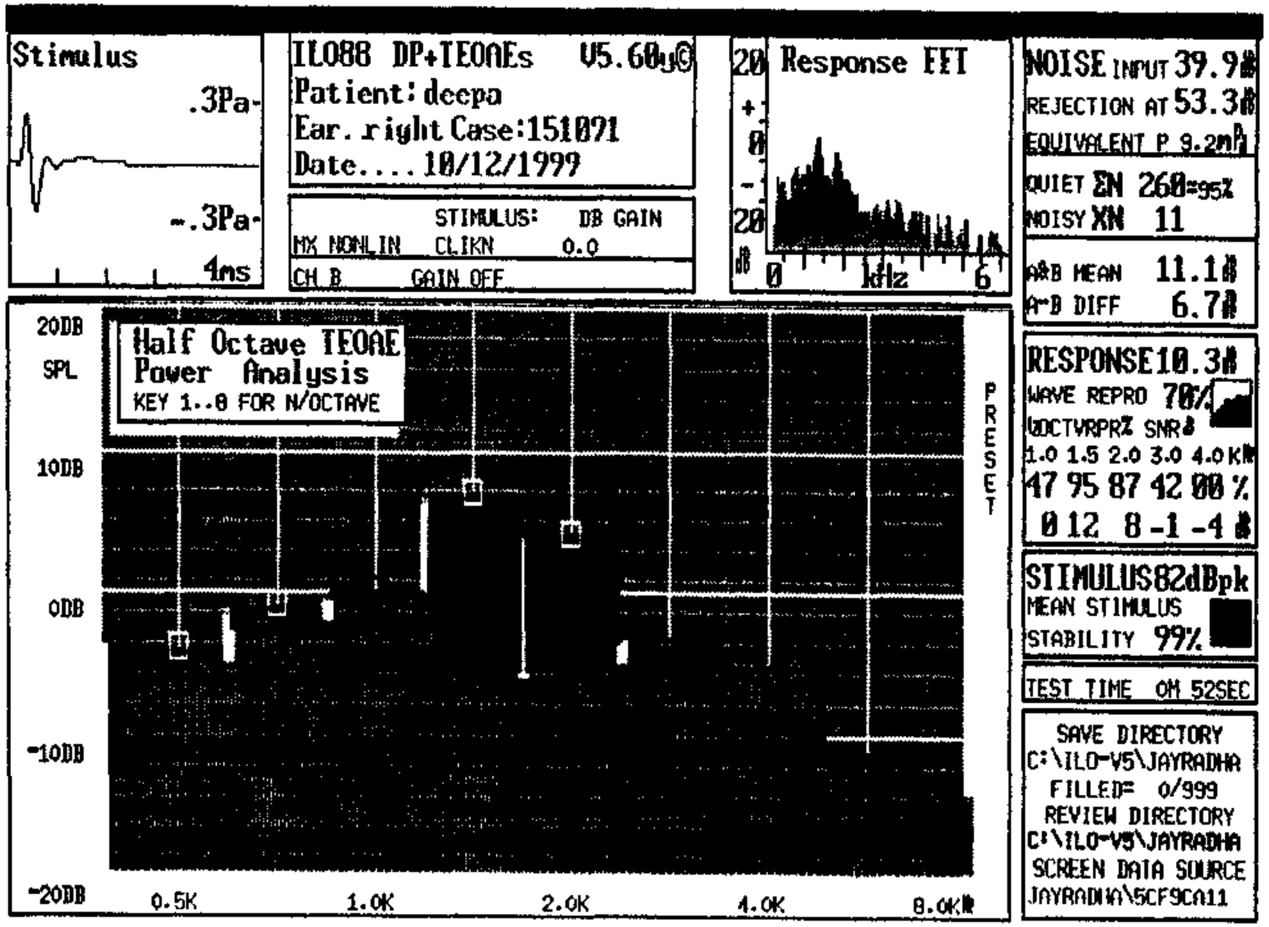

Fig 5.1 : Shows click evoked response in a case with minimal sensoryneural hearing loss.

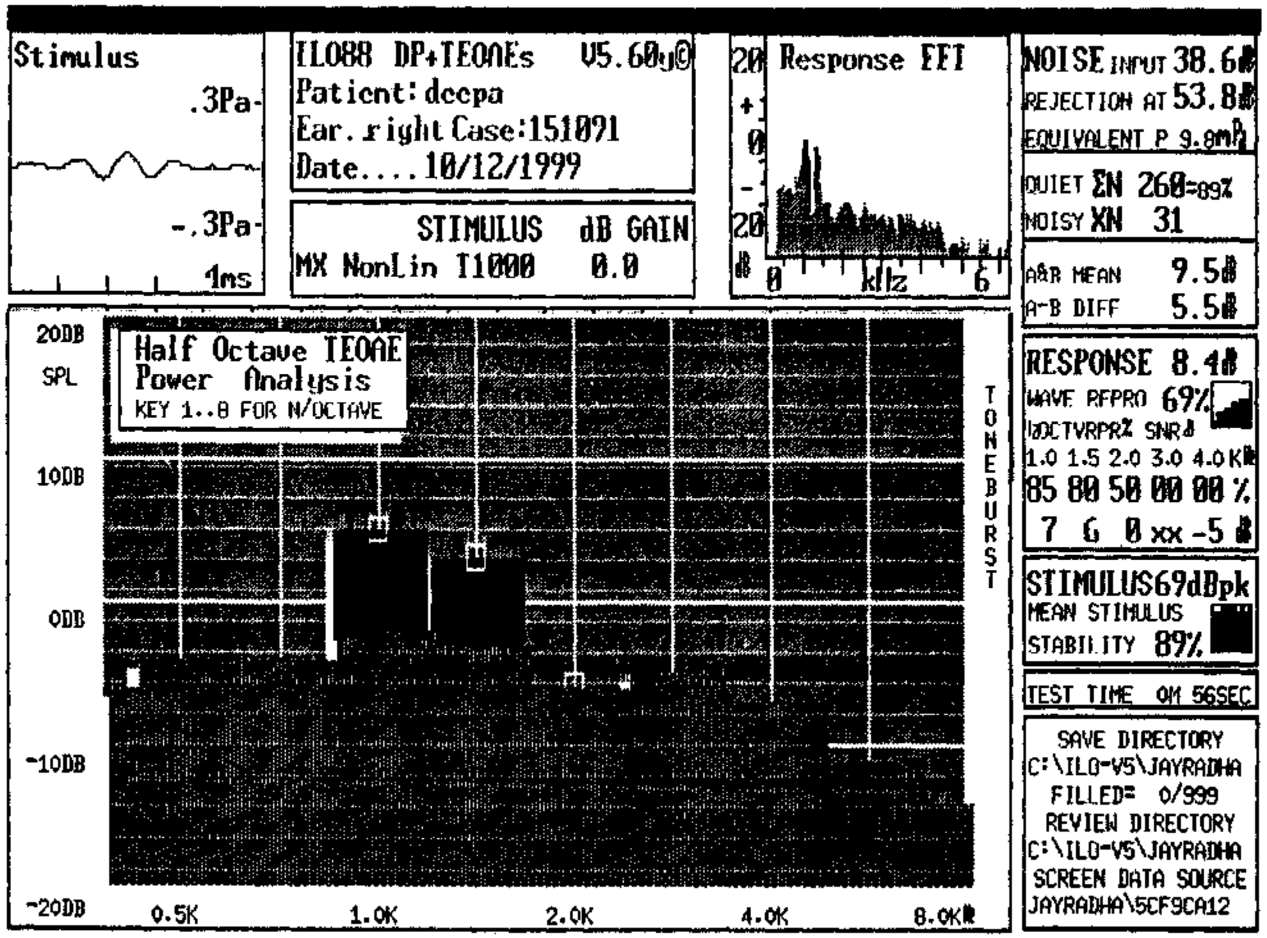

Fig 5.2 : Shows 1000 Hz tone burst evoked response in a case with minimal sensoryneural hearing loss.

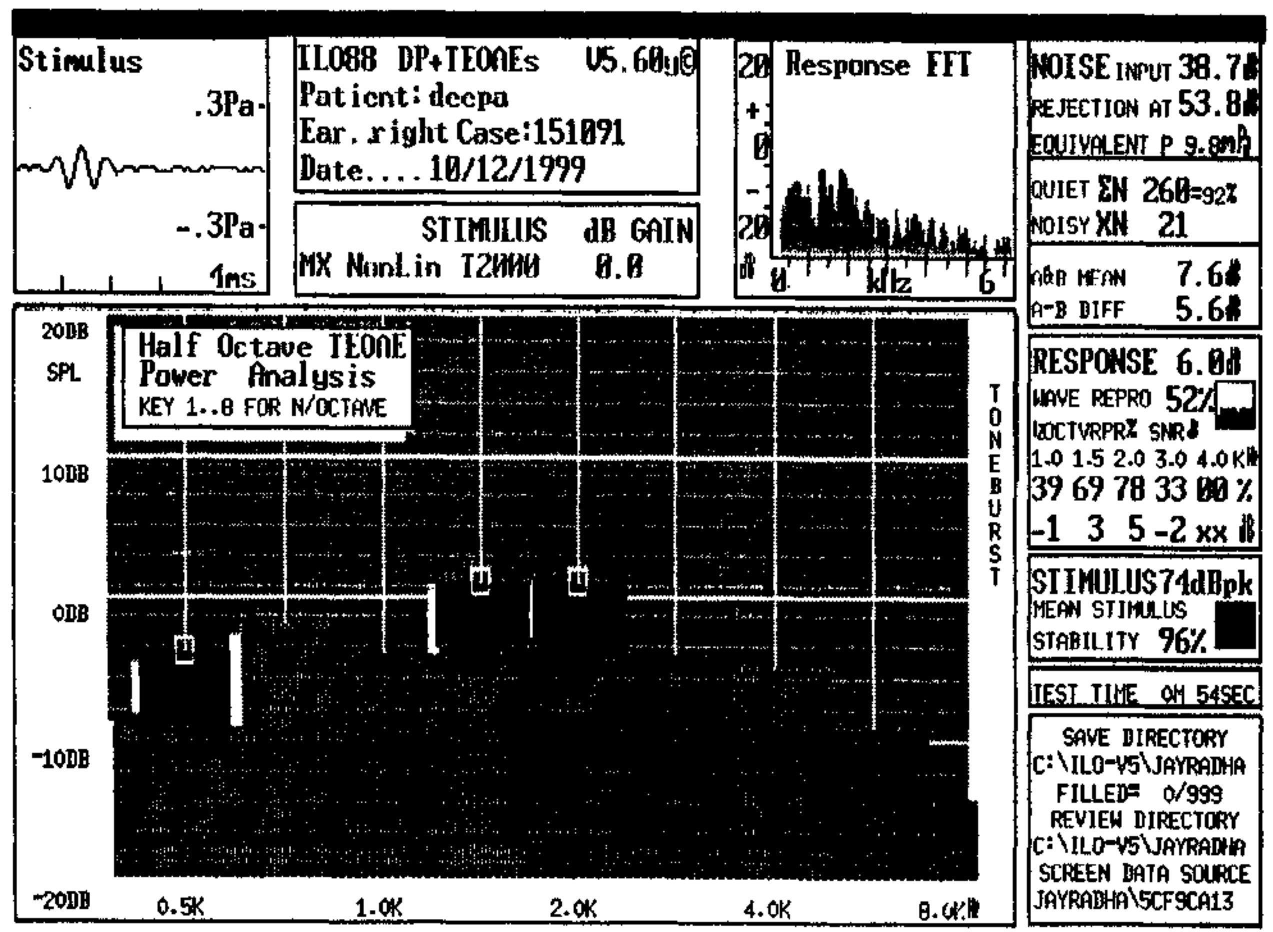

Fig 5.3 : Shows 2000 Hz tone burst evoked response in a case with minimal sensoryneural hearing loss.

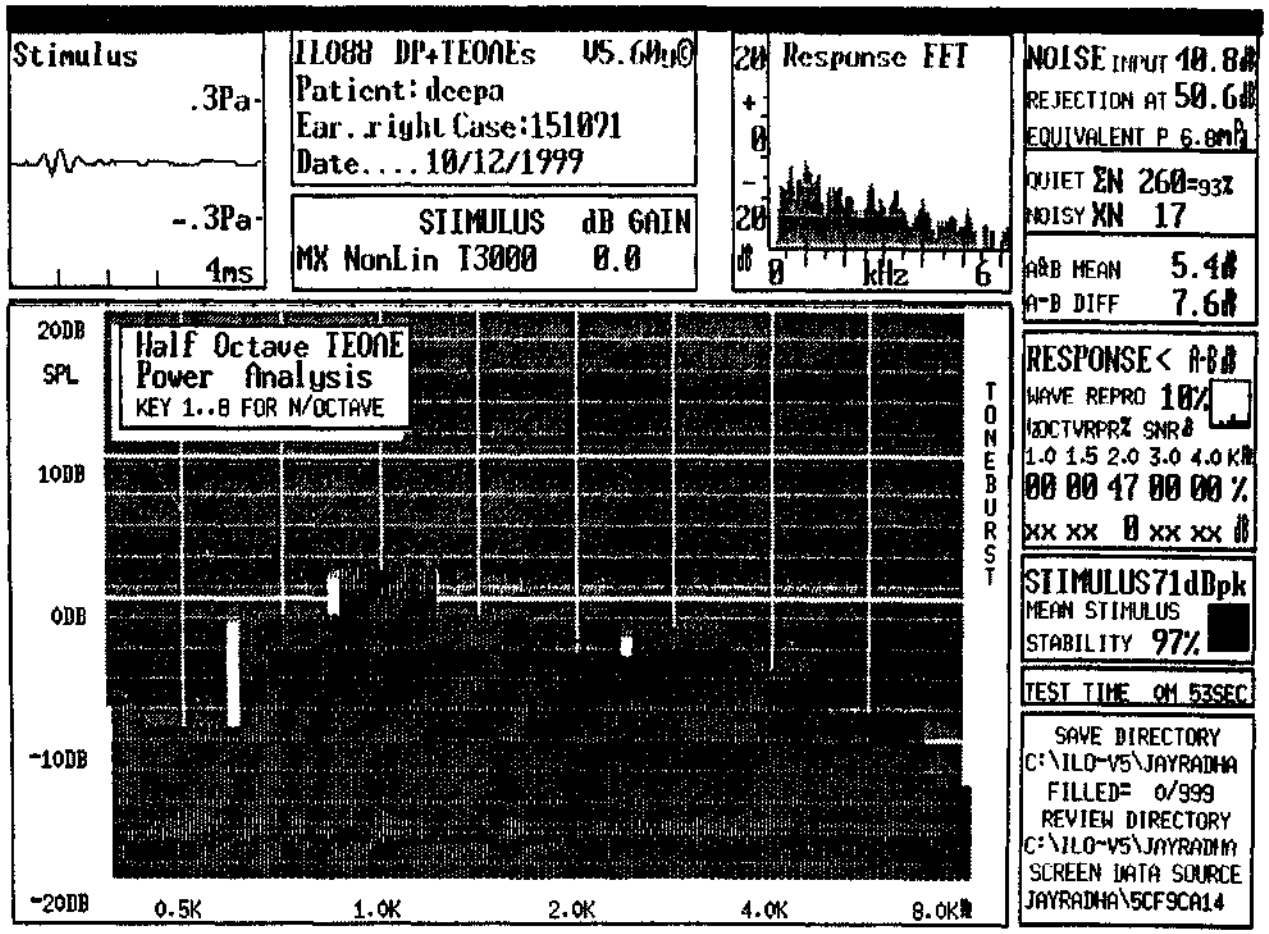

Fig 5.4: Shows 3000 Hz tone burst evoked response in a case with minimal sensoryneural hearing loss.

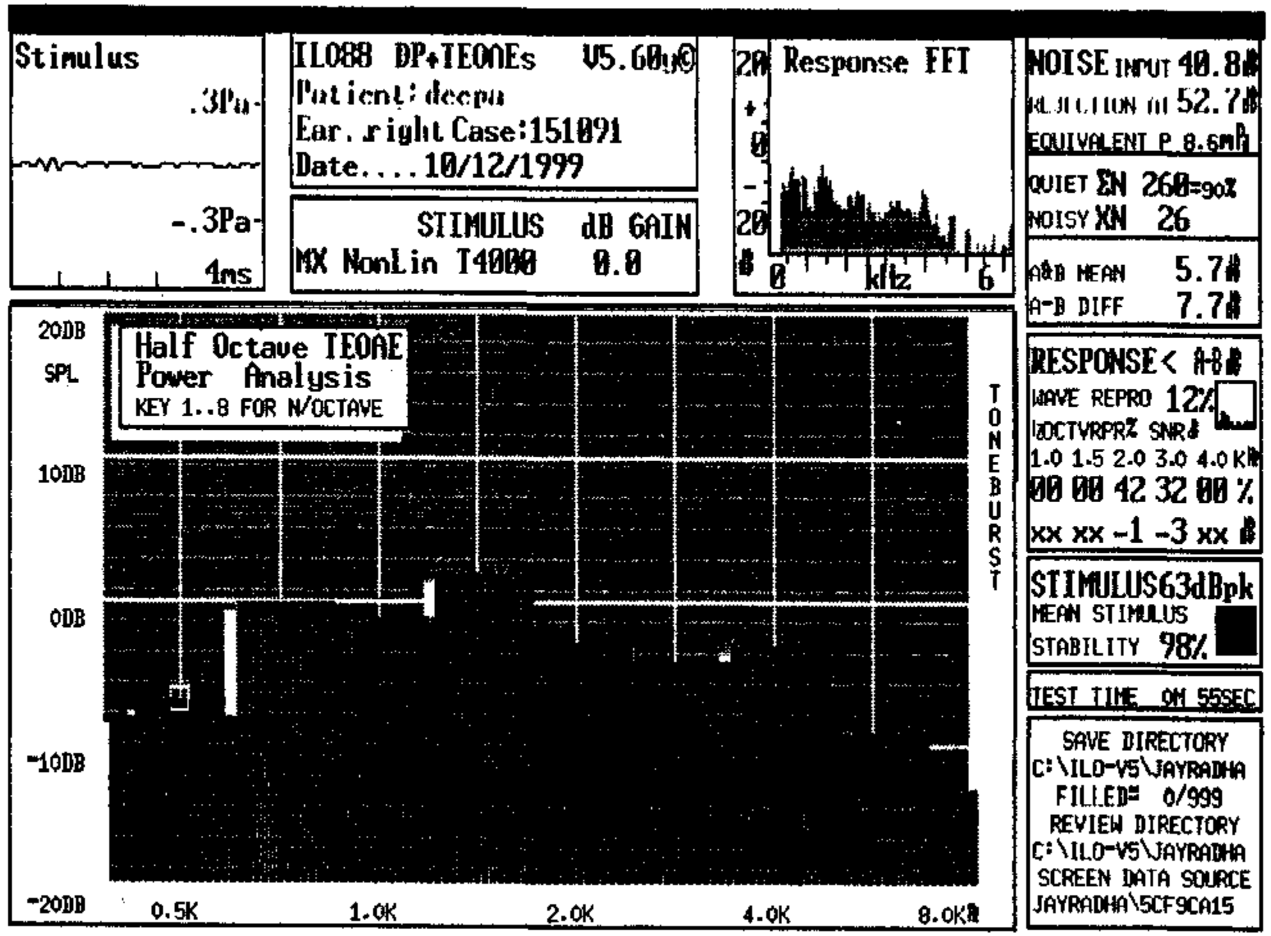

Fig 5.5 : Shows 4000 Hz tone burst evoked response in a case with minimal sensoryneural hearing loss.

RESULTS AND DISCUSSIONS

Clicks and tone bursts evoked otoacoustic emissions were compared in subjects with normal hearing and in subjects with sensorineural hearing impairment

The obtained data were analysed statistically and subjectively.

i. Comparison of clicks and tone bursts evoked TEOAEs :

' T ' test was carried out to find out significance of the difference in signal to noise ratio between the clicks and tone bursts evoked otoacoustic emissions. The obtained results are as follows :

Table 1: Indicates the mean, standard deviation and ' T ' values for the right and left ears in subjects with normal hearing.

Frequency	Intensity (dB)				' T ' Value
	Mean		Standard Deviation		
	C	TB	C	TB	
Right Ear					
1000 Hz	7.88	11.41	6.019	5.53	4.59*
2000 Hz	13.11	13.7	3.17	3.15	0.8137
3000 Hz	11.35	9.52	7.5	6.7	1.947
4000 Hz	9.17	9.58	7.23	7.77	0.4849
Left Ear					
1000 Hz	9.82	10.29	4.72	5.73	0.5301
2000 Hz	12.17	11	5.16	5.53	0.8725
3000 Hz	10.8	9.2	5.88	5.11	1.833
4000 Hz	7.29	8.11	5.93	4.93	1.072

C - Clicks. TB - Toneburst.

* Statistical significance at 0.001 level

In the right ear, the mean SNR values for tone bursts at 1000 Hz, 2000 Hz and 4000 Hz were greater man that of the mean SNR values for clicks. This difference was statistically significant only at 1000 Hz at 0.001 level. The difference in SNR values at 2000 Hz, 3000 Hz and 4000 Hz showed no statistical significance.

In the left ear, the mean values for 1000 Hz and 4000 Hz for tone bursts were greater than that of the clicks at the same frequencies. At 2000 Hz and 3000 Hz, mean SNR were greater for clicks than tone bursts. However, these differences were not statistically significant.

Probst et al. (1986) in their study reported that the tone burst emissions were often prominent than the click evoked emission which is similar to the results obtained in the present study. This could be due to the greater energy concentration of the tone burst evoking stimulus at l000Hz leading to greater SNR at that frequency which was further enhanced by the middle ear resonance frequency which is around l000Hz.

The possible explanation for greater SNR values for clicks at 2000 Hz and 3000 Hz could be the spectrum of clicks, where the peak equivalent SPL is greater than the tone burst evoking stimulus at those frequencies.

The responses at 2000 Hz for both clicks and tone bursts were greater than that it was obtained at 1000 Hz, which could be due to the biological noise, which is greater at low frequencies.

At high frequencies such as 3000 Hz and 4000 Hz (tone bursts), the SNR was lesser compared to the 1000 Hz and 2000 Hz tone bursts which could be due to the lower stimulus intensities at these levels.

The response of subjects with sensory neural hearing loss who had SNR below 3 dB were considered as zero for calculating mean, standard deviation and ' T ' value.

TABLE 2 : Shows the mean, standard deviation and ' T ' values for the right and left ears in sensory neural hearing loss cases.

Frequency	Intensity (dB)				' T' Value	
	Mean		Standard Deviation			
	C	TB	C	TB		
Right Ear						
1000 Hz	0.36	2.04	1.7	3.6	2.73	*
2000 Hz	1.54	1.00	3.1	2.7	1.96	
3000 Hz	0.95	0.45	2.75	2.13	1.46	
4000 Hz	0.909	1.36	3.47	4.27	0.773	
Left Ear						
1000 Hz	0.95	2.2	2.43	3.18	2.90	
2000 Hz	1.04	0.76	2.5	1.7	0.922	
3000 Hz	1.00	0.761	2.5	2.8	0.925	
4000 Hz	0.19	0.28	0.872	1.3	1.00	

C - Clicks. TB - Toneburst.

* Statistical significance at 0.05 level

In the right ear, the mean SNR values are greater for tone bursts at 1000 Hz, 4000 Hz and lesser at 2000 Hz and 3000 Hz than clicks. But the difference was statistically significant at 1000 Hz at 0.05 level. Similar results were obtained in the left ear also.

The explanations for the above findings would be the energy concentration at different frequencies and also peSPL for both click and tone burst evoking stimulus.

The mean SNR values for right and left ears were compared both in subjects with normal hearing and in subjects with hearing impairment.

Table 3: Depicts the mean, standard deviation and ' T ' values for right and left ears in subjects with normal hearing and in subjects with hearing impairment

Frequency	Mean Intensity				Standard Deviation				T Values	
	Clicks		Tonebursts		Clicks		Tonebursts			
	Right	Left	Right	Left	Right	Left	Right	Left	Clicks	Tone Burst
Subjects with Normal Hearing										
1000 Hz	7.88	9.82	11.4	10.4	6.01	4.72	5.58	5.78	1.19	0.682
2000 Hz	13.11	12.12	13.7	11.0	3.17	5.16	3.15	5.53	1.04	2.48*
3000 Hz	11.35	10.8	9.5	9.2	7.5	5.88	6.7	5.11	0.295	0.849
4000 Hz	9.17	9.5	9.5	8.11	7.23	5.93	7.77	4.93	1.17	1.20
Pathological Cases										
1000 Hz	0.363	0.909	1.72	2.18	1.7	2.3	3.4	3.1	0.838	0.497
2000 Hz	1.54	1.0	1.0	0.72	3.18	2.3	2.7	1.6	0.605	0.404
3000 Hz	0.95	0.95	0.45	0.18	2.75	2.75	2.13	0.85	1.46	0.451
4000 Hz	0.909	1.36	0.27	0.95	3.47	4.5	1.27	2.75	0.940	1.07

* Indicates statistical significance at 0.05 level

Although the mean SNR values in right ear were greater man that of in left ear except for clicks at 1000 Hz in right ear, these differences were not statistically significant except at 2000 Hz tone burst

In pathological cases, no significant difference was seen.

ii. Correlation between pure tone audiogram and TEOAE responses :

Pearson's product moment correlation was carried out to find out the correlation between clicks / tone bursts evoked otoacoustic emissions and pure tone thresholds.

Table 4: Shows the correlation values obtained for right and left ear in both subjects with normal hearing and in subjects with hearing impairment.

Frequency	Correlation Values			
	In Normals		In Pathologies	
	C & PTT	TB & PTT	C & PTT	TB & PTT
Right Ear				
1000 Hz	- 0.0158	-0.05	- 0.397	-0.45
2000 Hz	- 0.2804	- 0.286	- 0.577	-0.44
3000 Hz	- 0.0755	- 0.126	- 0.286	-0.162
4000 Hz	- 0.179	-0.05	- 0.290	- 0.221
Left Ear				
1000 Hz	-0.06	-0.017	-0.125	-0.144
2000 Hz	- 0.187	- 0.075	-0.32	- 0.409
3000 Hz	- 0.027	- 0.253	-0.27	-0.104
4000 Hz	- 0.235	- 0.439	- 0.202	- 0.202

C - Clicks. TB - Toneburst PTT- puretone thresholds.

The statistical analysis revealed negative correlation and hence there is a good correlation between the pure tone thresholds and TEOAE response for both clicks and tone bursts.

Negative correlation means mat whenever there is an increase in pure tone threshold, there will be an decrease in TEOAE SNR amplitude level. The pathological cases had better correlation than subjects with normal hearing.

In cases of sensorineural hearing loss with cochlear pathology, the cochlear dysfunction increases with the increase in puretone thresholds. Hence the SNR of the TEOAE decreases because the origin of OAEs are said to be the outer hair cells in the cochlea.

Similar results were obtained in a study by Bertoli & Probst, (1997). They reported that the response levels (SNR) decreased as hearing threshold levels increased.

iii. Finding out the degree and pattern of hearing loss using TEO AEs:

Subjective analysis was carried out to see the relationship between the degree of pure tone thresholds with the TEOAE responses.

Table 5: Depicts the percentage of the subjects who had emissions for clicks and tone bursts at 1000,2000,3000 and 4000Hz.

Pure Tone Thresholds	Frequency (Hz)							
	1000		2000		3000		4000	
	C	TB	C	TB	C	TB	C	TB
Within 15dBHL	82.5%	91%	100%	94%	97%	91%	79%	82.2%

At 1000 Hz and 4000 Hz the tone bursts have evoked responses in more number of ears than the clicks. At 2000 Hz and 3000 Hz, the clicks evoked responses were greater than the tone bursts evoked responses.

This could be due to the middle ear resonance, spectrum of the clicks and stimulus intensity levels which was found to be greater in clicks than tone bursts.

Table 6: Indicates the percentage of responses in individuals with sensorineural hearing loss.

Degrees of Hearing Loss	Frequency (Hz)							
	1000		2000		3000		4000	
	C	TB	C	TB	C	TB	C	TB
Minimal	4.5%	9.09%	6.8%	4.5%	6.8%	4.5%	2.2%	2.2%
Mild	0%	6.8%	0%	0%	6.8%	2.2%	4.5%	2.2%
Moderate	0%	2.2%	2.2%	2.2%	0%	0%	0%	2.2%

The 1000 Hz tone bursts have evoked responses in more number of ears than that evoked by clicks. The clicks evoked responses were seen only till a minimal degree at 1000 Hz.

At 2000 Hz, the tone bursts evoked responses were present in the less number of ears compared to clicks at minimal degree of hearing loss. At moderate degree of hearing loss, both clicks and tone bursts evoked responses are similar at 2000Hz.

Clicks and tone bursts evoked emissions were absent at 3000Hz when the individuals had moderate degree of hearing loss. At minimal and mild degrees, the clicks evoked, responses in greater number of ears than those evoked by tone bursts at this frequency.

Clicks evoked responses were seen at 4000Hz center frequency till mild degree of hearing loss where as 4000Hz tone burst could elicit response till moderate degree of hearing loss in some cases.

Over all the 1000 Hz tone bursts have evoked responses in maximum number of ears compared to the others, which could be due to the stimulus intensity levels, which was greater man that was in others frequencies. Also this could be due to the enhancement of the responses (SNR) due to the middle ear resonance which is around 1000 Hz.

At 2000 Hz, 3000 Hz and 4000 Hz, the clicks evoked responses were in more number of ears than those evoked by tone burst, because the stimulus levels (peSPL) for clicks was greater than that of the tone burst and also the click spectrum which showed more amplitude at these frequencies.

Stover & Norton, (1994) reported that the maximum threshold where a TEOAE response could be seen was 50 dBHL. In the present study TEOAE responses were seen when the pure tone thresholds were about 45 dBHL at 1000, 2000 and 4000 Hz where as for the clicks stimuli, response was seen at band width centered at 2000Hz.

It was also noticed that when there was a slopping / rising pattern of a hearing loss, the emissions were absent in almost all the cases those frequencies where there was a loss greater than 20 dBHL - 25 dBHL. This finding was similar to the study done by Johnson, parbo & Elberling, (1993) on mild to moderate, flat, steeply sloping hearing loss and they found that emission could be recorded in ears with significant high frequency hearing loss and no emission could be obtained from ears with a flat cochlear hearing impairment exceeding 40 dBHL in the midfrequency region.

Hence if the emissions are absent at all the frequencies, there is a possibility that it could be a flat hearing loss. If the emissions are present at two / more frequencies and absent at the other frequencies, it could indicate that the individual has either a rising / sloping audiogram configuration.

In the present study, the majority of subjects with sensorineural hearing loss, with a reproducibility rate less man 50 % did not show a TEOAE response. Similar result was reported by Kemp, (1988).

It could be noted that the stimulus level for tone bursts at all the frequencies were less than that of the clicks peSPL. Even though the evoking stimulus intensity was smaller, the amplitude of the responses for tone bursts were greater at certain frequencies. Hence the tone bursts gives an opportunity to have wider dynamic range. The broader spectrum of any acoustic stimulus increases the loudness and hence for a person with tolerance problem, it may be difficult to elicit a TEOAE response with clicks which has got a broader frequency range. So, use of tone bursts for those cases may be advisible. Not only this, even at frequencies such as 500 Hz and 1000 Hz where there is more biological noise, tone bursts can be used to elicit TEOAE responses.

Thus for screening purposes clicks can be used and for diagnostic purpose, tone bursts can be used.

SUMMARY AND CONCLUSIONS

OAEs are sounds found in the external auditory meatus that originate in physiologically vital and vulnerable activity inside the cochlea. The sound generated are small but potentially audible.

These emissions are generated either spontaneously or in response to acoustic stimulation (Kemp, 1978). One, among the evoked OAEs are the TEOAEs, which are frequency dispersive responses following a brief acoustic stimuli such as click or tone burst (Kemp, 1978 ; Norton & Neely, 1987) and found in nearly all persons who have normal hearing.

The TEOAEs obtained using clicks have broad response spectra. The tone burst evoked emissions have narrower bandwidth and energy is concentrated around the center frequency of the tone burst

Both click and tone burst stimuli for eliciting responses in ears with and without hearing loss have shown no significant advantage of using tone burst as stimuli (Kemp et al., 1986 ; Harris & Probst, 1991). However the amplitude of tone burst were found to be higher than the clicks (Probst et al., 1986).

The aim of the study was to compare clicks and tone burst evoked emissions in subjects with normal hearing and in subjects with sensorineural hearing loss.

The subjects for the study consisted of 17 adults (34 ears), aged 15-50 years with normal hearing and 22 adults (44 ears) aged 15-50 years with minimal to moderate sensorineural hearing loss with different configuration. The following results were obtained.

i. The signal to noise ratio comparison between CEOAEs and TBOAEs in normals and in pathological ears showed significant differences at 1000 Hz in the right ear for subjects with normal hearing. In pathological cases also the above results were obtained in both the ears.

ii. The comparison of SNR for clicks and tone bursts evoked responses between right and left ears in normals and pathological ears showed no significant differences except at 2000 Hz in normal ears.

iii. There was a good correlation obtained between TEOAE responses and puretone thresholds.

iv. Greater number of ears showed responses for clicks at 2000 Hz and 3000 Hz and tone bursts at 1000 Hz and 4000 Hz. TBOAE were seen when the puretone thresholds were about 45 dBHL at 1000 Hz, 2000 Hz, 4000 Hz tone bursts and bandwidth centered at 2000 Hz for the click stimuli.

v. In cases with sloping / rising pattern of hearing loss, the emissions were absent in most of the cases at those frequencies where the loss was greater than 20 - 25 dBHL.

vi. Reproducibility rate less than 50 % did not show any TEOAE response. The amplitude of the tone burst evoked responses were greater than CEOAEs at certain frequencies though the peSPL for clicks were greater than the tone bursts.

Tone bursts as a stimuli is advisible for the persons who has got a tolerance problem. At frequencies such as 500 Hz and 1000 Hz, where the biological noise is more, tone bursts can be used. Thus for the purpose of screening for hearing loss, a broad band stimuli such as a click can be used, which does not require more time for testing and for diagnostic purpose especially with the slopping / rising pattern of hearing loss tone bursts give better results.

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