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Auditory Assessment Based On EEG

Ms. Divya Rengarajan, Mr. Bhavin Mehta, Ms. P. Vinupritha

Abstract— Auditory assessment is based on the determination of hearing threshold of the subject. The hearing threshold is minimum sound power level (dB) of the stimulus audible to subject. The subject's response to the stimulus is present in the electroencephalogram (EEG) as auditory evoked potential (AEP) once the stimulus is loud enough to excite the auditory system. The present paper reviews a real time auditory assessment method by plotting an audiogram on the basis of AEP using LabVIEW.

Index Terms—hearing threshold, auditory stimulus, auditory evoked potential (AEP), electroencephalogram (EEG), auditory loss, steady state auditory evoked potentials, audiogram, auditory steady state response (ASSR), amplitude modulated (AM), LabVIEW, virtual instrumentation (VI).

1 Introduction

Hearing impairment is a health disorder significantly seen in two ends of human life, approximately one in thousand new born infants and more than a quarter of adults over the age of 65years have significant auditory loss. Early detection ensures provision of appropriate treatment at an early stage and thereby ensures development of normal speech and language in infants. In the case of adults this technique will help in choosing the perfect hearing aid. Conventional screening techniques use an audiometer which needs a behavioral response from the subject. In the case of elderly people and infants, they won't be able to provide any substantial response and in the other case which is of mentally challenged patients, they won't be willing to take the screening test. Thus this paper goes in the direction of reviewing another means to detect auditory loss so that early and accurate diagnosis is possible. This technique focuses on determining hearing thresholds at different frequencies based on the response of brain to the auditory stimulus through auditory evoked potential that are present in EEG. Auditory evoked potentials are small electrical potentials generated in brain in response to any auditory stimulus and recorded from scalp. The steady state auditory evoked potentials are the responses obtained when stimuli occurs at a rapid rate in such a way that the responses superimpose and cause a periodic responses at specific stimulation frequencies. This enables us to record the response at multiple frequencies and plot the frequency versus sound power level as an audiogram for further analysis. When the auditory evoked potentials are generated due to stimulus at a higher rate it gives rise to auditory steady state response (ASSR). Stimulus of amplitude modulated tones with carrier frequencies of 500, 1000, 2000, 4000Hz elicited ASSR and it was seen that there is no significant difference between single and multiple AM tones [1]. For the same stimuli the difference between mean evoked potential thresholds and behavioral pure tone thresholds was taken and it was found that for 40Hz ASSR the difference was less compared to 80Hz ASSR [5]. The monotic ASSR is 0-10 dB higher than the behavioral ASSR threshold and also there is no difference between dichotic and monotic stimulus [2]. Chirp stimulus generates responses with larger amplitude than click stimulus and the responses at 40Hz repetition rate are larger than that at 80Hz [3]. The scalp distribution of both stimulus evoked and event related components of response vary with age yielding an equipotential distribution in older subjects. In children the latencies of event related potentials decreases with age [4]. It is also noted that the ASSR amplitudes and phases did not differ for single versus alternated stimulus polarities for both bone- and air-conduction stimuli [6]. Furthermore the AEP can provide the information about number and location of existing auditory nerve fibers as shown by using 40Hz AEP response [8].This article discusses the method of stimulus generation, simultaneous EEG signal acquisition, analysis of the auditory evoked potential in the background EEG and plotting of an audiogram of the subject for the purpose of diagnosing him/her for hearing related disorder.

- *Divya.Rengarajan is currently pursuing masters degree program in biomedical engineering in SRM University, India, E-mail: deevyaa@gmail.com*
- *Bhavin Mehta is currently pursuing masters degree program in biomedical engineering in SRM University, India, E-mail: bhavin.bme@gmail.com*
- *Ms. P. Vinupritha is currently working as an assistant professor (O.G) in deptt. Of Biomedical Engineering, SRM University, India.*

2 Materials And Methods

This section discusses the hardware and software components used and also the process of signal acquisition, processing and analysis. The basic system representation is shown in fig.1. The system consists of both hardware and software components and can be used with a PC to collect and analyze auditory steady state responses and also facilitates research with ASSRs. This system can be also used as objective audiometry for hearing assessment. As the system should use standard hardware and flexible programming system, hence LabVIEW was used as a data acquisition platform.

2.1 System Requirements

The software and hardware components are as discussed below.

LabVIEW is a graphical programming language that lets us make programs in form of virtual instruments (VIs) which look and act like real instruments and also can be interfaced with many hardware devices using data acquisition cards. For the data acquisition board National Instrument's ELVIS Prototyping Board is used which has nearly seven physical channels, each of which is differential in nature. In this the signals are differentially amplified to a level that the signals usually in range of 10μV can be conveniently viewed in the PC.

DAQ hardware which is a basic A/D converter provides the interface between the real world signals and the PC containing LabVIEW. It can be in the form of modules that can be connected to the computer ports (serial, parallel, USB etc.) or cards connected to the slots in the mother board.

2.2 Stimulus Generation

Variable frequency and variable amplitude sinusoidal waveform is generated using LabVIEW. The waveform is then amplitude modulated with 40 Hz sinusoidal wave [5]. This modulated wave is then played via sound output write and sound output start Vis. Also volume control is done in order to decrease or increase the stimulus sound level thereby getting a variable dB level sound which will further enable us to accurately measure the hearing threshold of the subject.

The octave analysis is done on the sound stimulus which consists of 1/3 fractional analysis with exponential weighting. Thus both the octave graph and total band power is displayed. The frequency of stimulus presented is calculated via tone measurement and displayed on a numeric indicator.

2.3 EEG Acquisition

The EEG signal acquisition is based on the 10-20 lead system. We use an ipsilateral montage. For the recording of EEG, here we use a 3-electrode system. In this system the electrode positions used are Fp, Cz and in any one of the ear lobes as active and reference electrodes. All the electrodes used are simple Ag/AgCl surface cup electrodes and measure the scalp potential.

The electrical activity recorded from scalp is usually in range of ±20μV, thus for amplification before reaching AD input of data acquisition board, a small battery operated EEG amplifier is used having a gain of 10000 and high pass filter 1Hz and low pass filter of 300Hz.

After the EEG signal is acquired, the fast Fourier spectrum (FFT) is taken and the power spectrum of the signal is displayed. The EEG signal is then filtered using butterworth IIR filter having specifications:
Low pass filter, 3rd order and low cutoff frequency at 40Hz.
Again it is filtered out with IIR smoothing filter. As the EEG waveform is complex in nature, band separation has to be done and then only any special increase or decrease in the amplitude and frequency of those bands can be observed. The four frequency bands are alpha (8-14Hz), beta (14-20Hz), theta (4-8Hz) and delta (0.4-4Hz). In order to do these separations of bands into different frequencies butterworth infinite impulse response filters (IIR) are used as band pass filters as they have better pass band ripple attenuation compared to other classes. The specifications for designing the filter are:
Filter of order 3 having pass band ripple as 1, stop band attenuation as 60dB and the upper and lower cutoff frequencies set according to the wave's frequency range mentioned above.
Each of these frequency signals are then fed to the tone measurement express VI which extracts the frequency, amplitude and the phase information of the specific wave at that particular time. These readings can be used to evaluate the response of brain to any stimulus.

2.4 Testing And Analysis

Firstly, the frequency of stimulus is set by frequency control and amplitude control is set to zero, then stimulus is given to subject and simultaneously EEG is recorded and displayed. The physician observes the EEG for AEP waveform in order to get ASSR, especially N1-P1 peaks are searched for. The amplitude control is continuously incremented to increase the volume of the stimulus. The moment the AEP waveform is seen the physician should press the record button, and thus that particular frequency and dB level is updated on the table and the audiogram is simultaneously plotted. Then the frequency control is moved to next frequency on which again the same procedure is performed to get hearing threshold. And thus, the hearing thresholds at all desired frequencies can be found.
The automatic analysis provision for determining the type of hearing disorder is also incorporated by comparing each hearing threshold value with standard range and thus an indicator of patient's condition such as normal, mild, severe and profound is provided in the front panel.

3 Results and Discussions

The following results have been obtained and are discussed in this section:

1. The fig. 2 shows the data obtained from recording session by presenting stimuli to both the ears and recording the EEG by varying both amplitude and frequency control.
2. Auditory evoked potentials are only seen in delta waves when stimulus is provided and no change is seen in any other brain wave as shown in fig. 3. As the evoked potential due to sound stimulus are generated and their frequency match to that of delta waves and hence the temporal change in the delta wave is seen.
3. The disorder specific audiograms were taken from different subjects such as the cases ranging from normal, mild, mixed and severe hearing loss were analyzed by the system and the results of which closely adhered to the conventional audiometry. These system recorded audiograms along with the frequency and dB level table are shown in fig. 4, 5 and 6.

4 Conclusion

The discussed system is windows based system for real time acquisition and analysis of auditory steady state responses which can be used as objective audiometry.
The system is designed to be flexible and user friendly. The system has simple hardware and software requirements. The

system was successfully tested on subjects with different hearing disorder and the results were found to closely adhere to conventional subjective audiometry.

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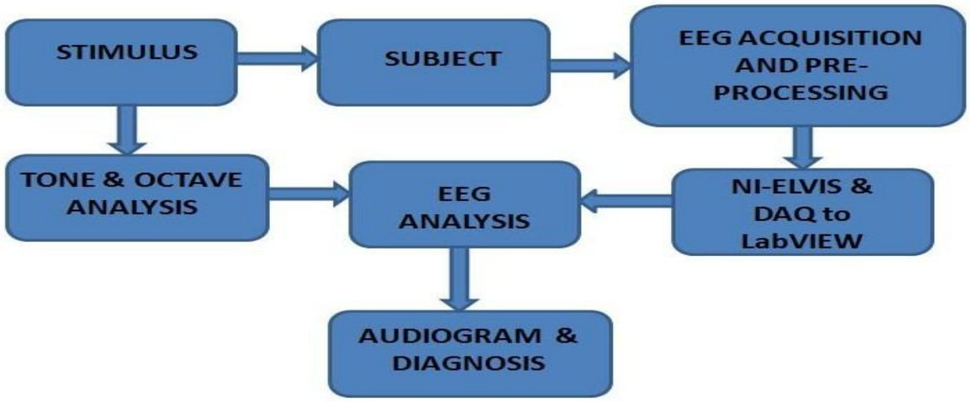

Fig. 1: System representation

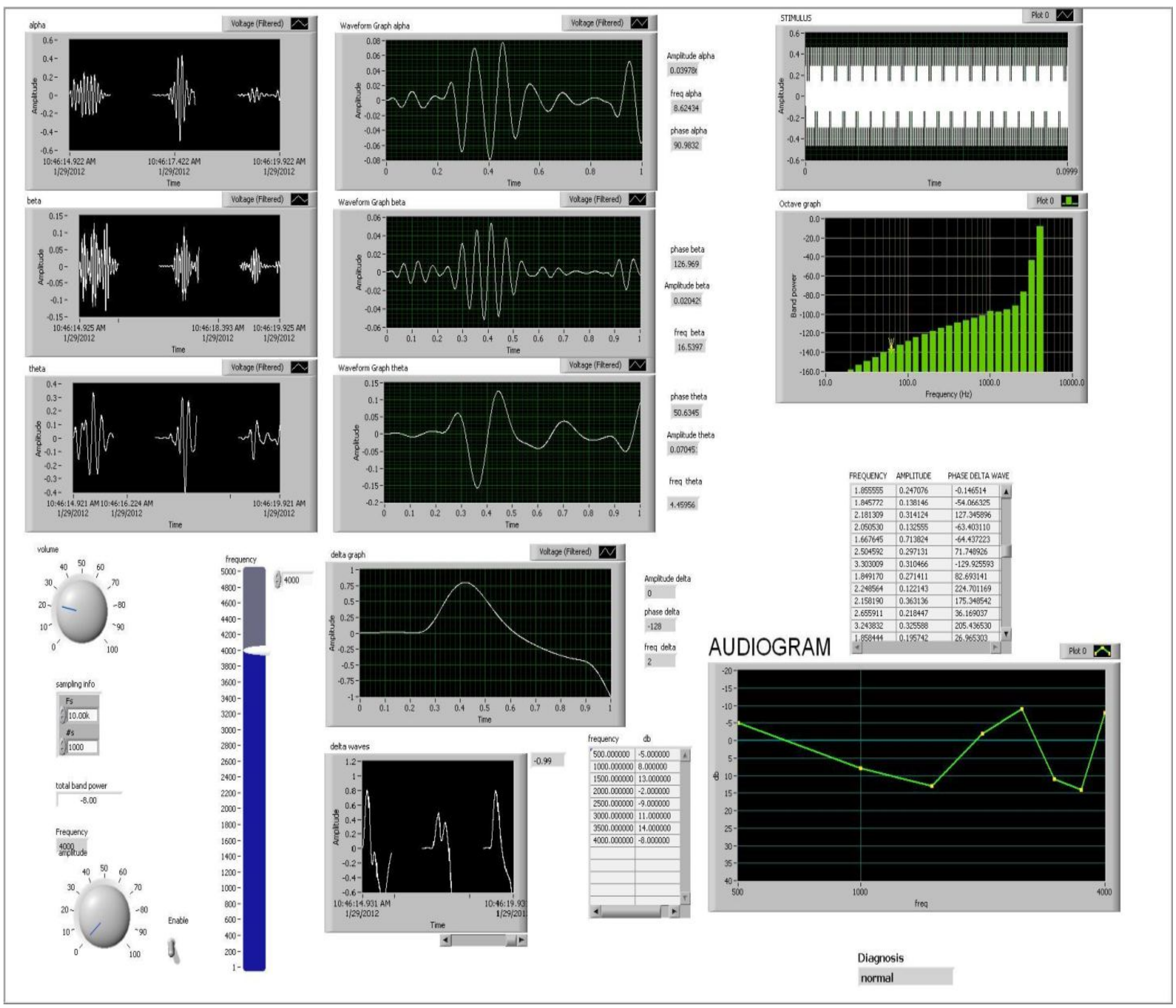

Fig. 2: Audiogram obtained from recording session by providing stimulus on both the ears

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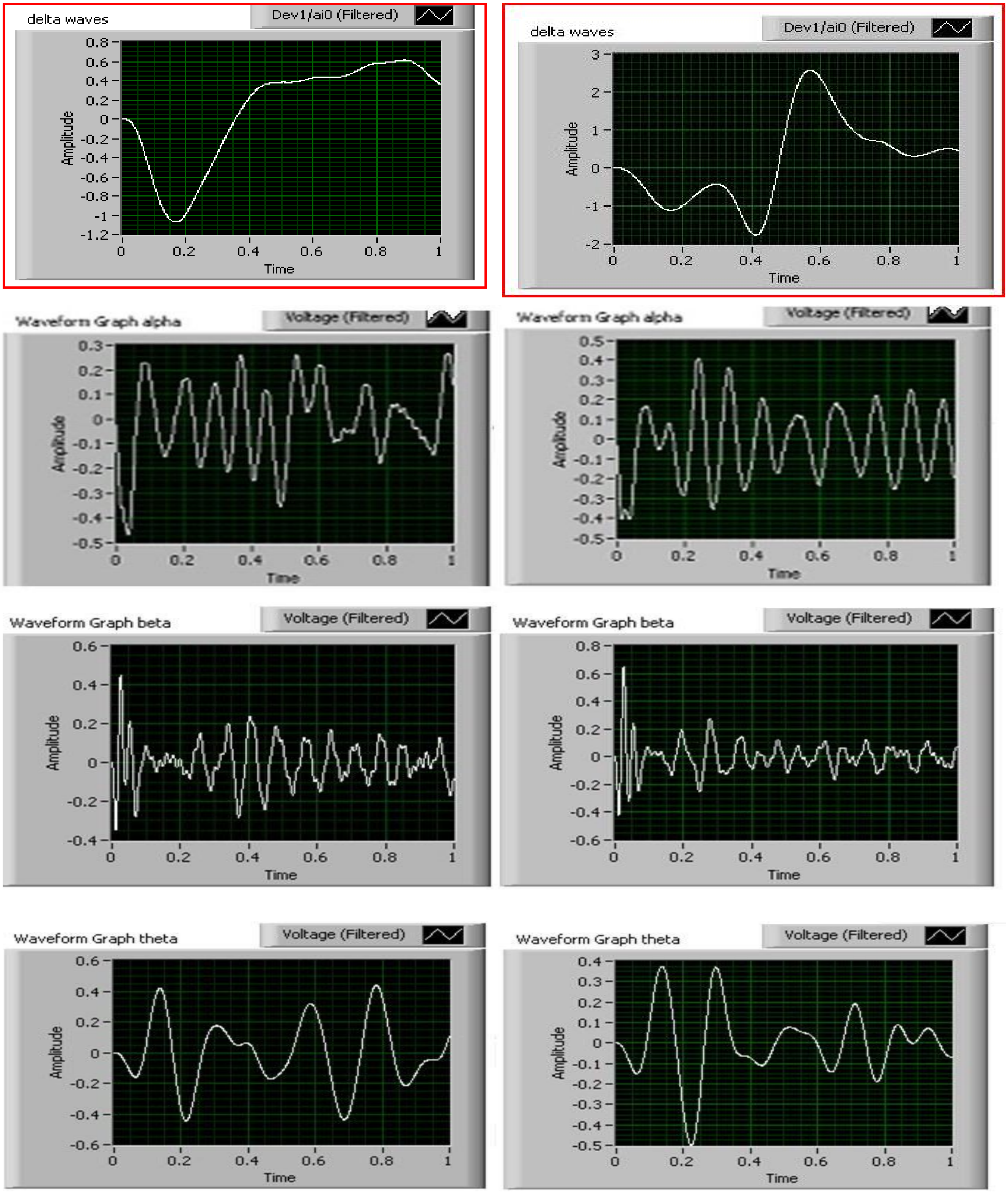
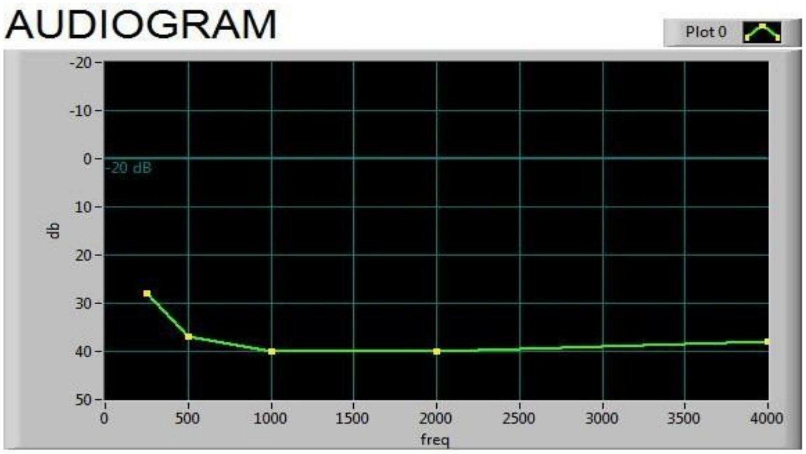
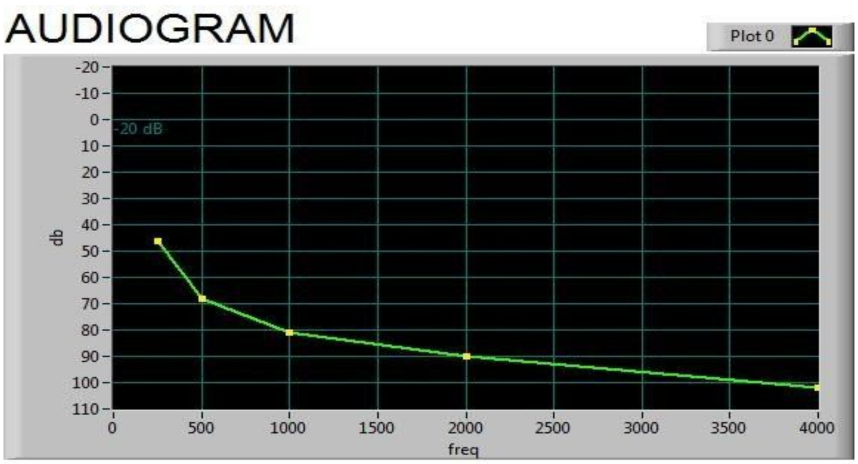


Fig. 3: The brain waves recorded before and after application of stimulus.



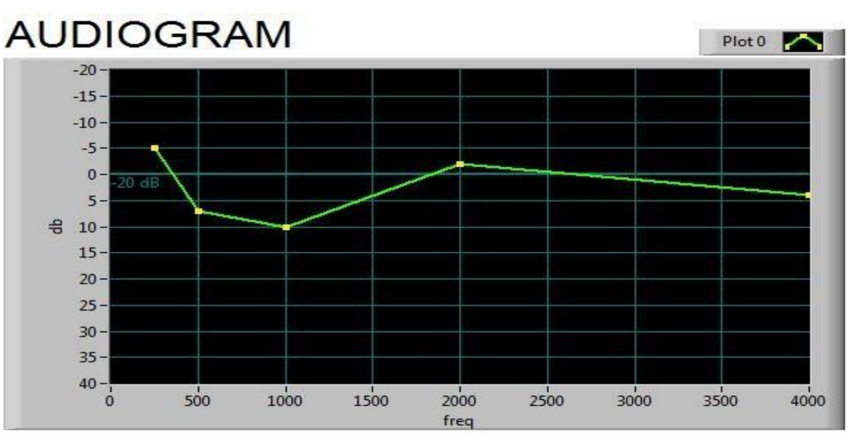
frequency	DB
250.000000	28.000000
500.000000	37.000000
1000.000000	40.000000
2000.000000	40.000000
4000.000000	38.000000

Fig. 4: audiogram obtained for mild loss case



frequency	DB
250.000000	46.000000
500.000000	68.000000
1000.000000	81.000000
2000.000000	90.000000
4000.000000	102.000000

Fig. 5: Audiogram obtained from sensorineural severe loss case



frequency	DB
250.000000	-5.000000
500.000000	7.000000
1000.000000	10.000000
2000.000000	-2.000000
4000.000000	4.000000

Fig. 6: Audiogram obtained from a normal case.