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Portable Audiometer for Detecting Hearing Disorder at an Early Stage for Cancer Patient

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***Abstract*—Cancer treatment requires heavy dose of drugs which can affect hearing capacity. In such case it is very essential to monitor the hearing capacity of the patients continuously so that hearing disorder can be detected at an early stage. Portable audiometer can prove to be a powerful tool for preventing the hearing disorders in patients. Portable audiometer consists of a hardware unit which is connected to a pair of earphone and a patient response switch. The frequencies of the audible range are transmitted to the patient through the ear phone. The recorded response is transmitted to the health care unit. This paper describes the design technology of portable audiometer which includes audible range test functionality and is capable of early detection of hearing changes. The system includes a wireless cellular modem which is capable of notifying a remote healthcare professional of the hearing test result.**

***Keywords*- Audible range audiometry, hearing screening, hearing loss monitoring, remote health care.**

I. INTRODUCTION

If someone is unable to hear any sound from the audible frequency range then that is known as partial or total hearing loss. It may be temporary or permanent. Hearing loss may be due to various factor like over medication, infection,sensation of neural loss due to ageing etc. Treatment of some major diseases like cancer often results in the hearing loss as a side effect of heavy medications[9] [10]. Several studies have found that exposure of high dose drugs during chemotherapy, occupational noise and genetic origin may cause adverse effect on hearing ability. Frequency ranges from 9 to 20 kHz is useful for early diagnosis of hearing loss[11].

Human ear are having different parts. When defects in the ear drum, ear canal and its little bones are responsible for the hearing loss then it is known as conductive hearing loss where as if nerve related problems are responsible for hearing loss then that type of loss is known as Sensorineural hearing loss. If the damage caused by both then that is called as mixed hearing loss[12].

The process by which we can measure the hearing capacity is known as Audiometry and the instrument used for it is called as an Audiometer. This technique helps the doctors to analyse and judge the hearing capacity of the patient so that suitable medical treatment can be prescribed at an early stage.

Portable audiometer can prove very useful in the time detection of such effects. This system can be used by the patient himself even in the absence of the trained operator once he/she learns the testing process. By using this device, tones of varying frequencies and amplitude levels are generated. These test tones are then presented to the patient and the response is recorded. On the basis of this recorded response the hearing thresholds of the patient are determined.

At ENT clinics, hospitals and audiology centres audiometer is found as a standard equipment. There are several types of audiometers like hardware audiometer and software audiometer. Audiometers are also used for industrial audiometric testing applications.

According to the recent literature, it is observed that every year, 1.3 million Americans are diagnosed with cancer out of which 16 percent receive a diagnosis of lung or head and neck cancers[4].

Depending on the stage of cancer, patients with lung, head, or neck cancers are given a treatment with the drug chemotherapy. Excessive dosage of this drug often results in a hearing shift in approximately 60 percent of adults and children[2][3]. Hence the development of accurate and precise audiometric device is needed so that the hearing hazards caused to the patients can be prevented. According to the recent biomedical literature, it is observed that many researchers are working in the direction of developing more accurate audiometric devices that are easy and robust to use. In[1]Nakamura described a mobile audiometric testing system that uses the mobile phone as the operating platform. However, in such systems it is a very challenging task to obtain an audio signal of the required purity. Further, in[1] the author does not show performance results with the sound signals having frequencies above 10 kHz. Working in the similar direction, some other researchers have designed portable audiometers using desktop personal computers[5] , hand-held computers[6] etc.

Hearing test at clinics may not provide early detection of hearing shift within two or three weeks interval. The advancement of technology provides better access to health care services. American Speech-Language-Hearing Association's technical report strives to develop and to validate remote practice clinical protocols in audiology. There is an essential requirement for technology which would permit auditory testing at home by the test object and the technology would enable delivery of the results via a secure Health Insurance Portability and Accountability Act compliant network to the health care team and would improve healthcare access for patients.

The objective of this paper is to continuous monitoring of patient who used the hi dose of medicine which affect the

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hearing sensitivity and for normal hearing screening test. The comfort level of the patient increases by using this system.
Rest of the paper is organized as follows: Section II explains the block schematic for portable audiometer in detail. Process flow are given in section III. Experimental set up are given in section IV. Experimental results and discussion are given in section V. Finally, conclusion of the paper work is given in section VI.

II. SYSTEM DESIGN

This system consists of 1) AVR-based processor (Arduino, ATmega-328) with 20*4 LCD monitor; 2) an audiometer with an audible range capability printed circuit board (PCB) for generating pure tone audio; 3) Sony earphones; and 4) SIM 900- MHz cellular network modem which is used for transferring diagnostic results to an audiologist. The audiometer, LCD and cellular modem are combined in a comfort designed portable package with protective carrying case.

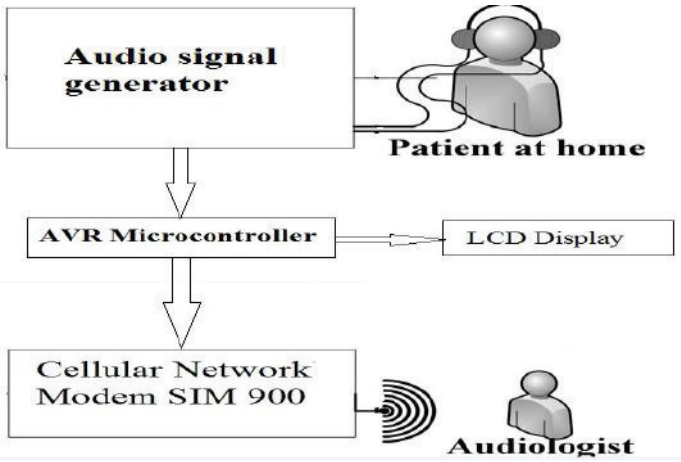


Fig. 1. Portable audiometer basic blocks.

For home use this type of portability is the key requirement. A system design of this system is shown in Fig 1. Figure 1 shows that Portable audiometer which includes AVR based micro controller, 20*4 LCD display, audiometer and a cellular modem for remote health care facility.

Figure 2 shows the block diagram of Proposed Portable Audiometer. Detailed explanation of each block for an portable audiometer is given below:

A. Function Generator:

Function generator is an electronic device used to generate different frequency ranges between 20 Hz to 20kHz. The audiometer uses the frequencies range between 250Hz to 8 kHz and these ranges are used by audiologist for hearing test. The system uses ICL 8038 to generate pure tones for hearing test and it produces sine, square and triangular waveforms. The distortion of this waveform should be minimum and ICL 8038 gives the waveform with very little distortion so the system uses ICL 8038. The loudness of sound depends on an amplitude of the signal and the pitch of sound depends on frequency of the signal. The frequency and amplitude of

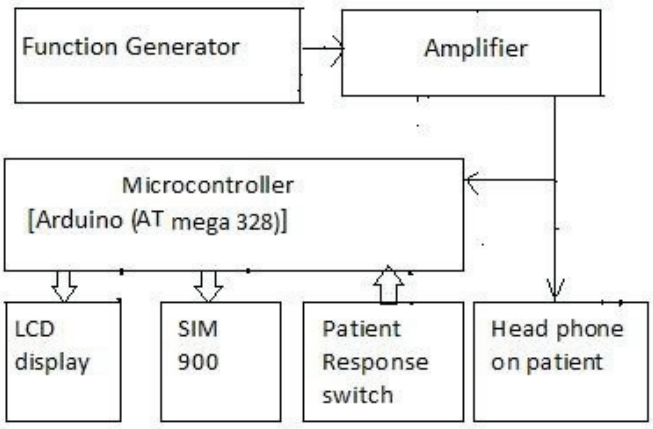
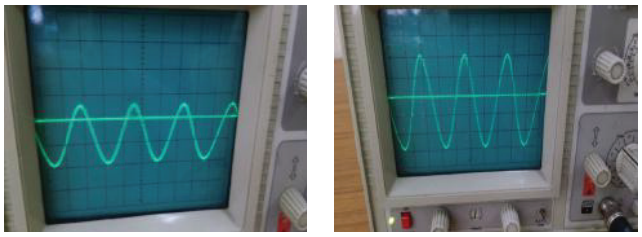


Fig. 2. Block diagram of Proposed Portable Audiometer.

signal generated by function generator can be vary by varing the variable resistance. The rotary switch is connected to vary the frequency. Test object varies the frequency by using rotary switch. Proposed system gives very high resolution of frequency, where as of now, available audiometers are unable to generate this much resolution of signal for hearing test.

B. Amplifier:

An amplifier is an electronic device which can increase the strength of a signal.It takes power from supply and controls the output to match the input signal shape, with larger amplitude. By doing this it modulates the power supply output witch is based upon the input signal.Amplifier amplifies the audio signal. A POT of 10 k as a rotary switch is used to increase or decrease the amplitude of the signal as shown in figure 3, we are using LM324 as audio amplifier.



(a) Amplitude variation(low) (b) Amplitude variation(High)

Fig. 3. Amplitude variation by using rotary switch

C. Micro controller:

In proposed system we used the Arduino UNO which is based on the Atmega328 processor which is an open-source physical computing platform based on a simple I/O board. The programming language for the Arduino Microcontroller is implemented in embedded C language. Micro controller is connected to function generator, LCD display, SIM 900 and patient response switch. LCD shows the frequency received by the patient from head phone, using micro controller. Patient response switch is connected to Micro controller. Patient responds according to the received signal from function generator. That response is saved in micro controller, and that

data is then sent to the health care unit via SIM 900. This system uses AT mega 328, for record the patient, transmit the recorded response to health care unit. Microcontroller receives the signal value and transmits it to LCD display.

D. LCD Display:

The main purpose of LCD is to display frequency and intensity of the transmitted signal. The frequency is verified in DSO (Digital Storage Oscilloscope). DSO shows the same reading which is shown in LCD by varying the frequency.

E. S I M 900:

Internet and high speed data access are carried over high frequency networks were as Cellular network voice communications and SMS text message can be use in low frequency. For simple messaging services we can use over low-frequency networks. SIM 900 MHz cellular network modem is used to transmit patient test result to the healthcare unit as a text message. Clinician's phone number is fed into the micro controller by programming. By using a 900-MHz modem access to low-frequency networks is obtained. when patient respond on patient response switch, the response is recorded in micro-controller and text message is send to the mobile number which is fed in micro-controller.

F. Patient Response Switch:

The patient response switch is operated by patients or test object. If the particular frequency is to heard by patient, he/she Press the response button. If that particular frequency unable to hear by patient then he/she press the response switch. The patient's response is sent to the micro controller. Micro controller save that response and sends it to the health care unit.

G. Ear Phone:

Ear phone are used for audiometric test. At a time patient have to use one ear phone to one ear and perform the hearing test. There is a switch selector which is used to select the left/right ear phone. To avoid the false response proposed system used to mask the another ear which is not in use for test. If the right ear is tested then left ear is at rest, that is, left ear does not receive any signal. The same process is done for left ear test. At the time of left ear testing process, only left ear uses the ear phone to get the signal and test object respond accordingly.

III. PROCESS FLOW

Normal hearing capacity of human ear is 20 Hz to 20 kHz. For hearing test, we generate minimum frequency as 250 Hz and maximum frequency as 8 kHz. From the ear phone patient/test object receives the frequency. There is a nob to increase or decrease the frequency and intensity. Proposed system used the variable resistor for varying the frequency and intensity.
Initially patient gets 250 Hz frequency by the ear phone, if patient are able to hear that frequency, he/she increase the frequency and intensity and respond accordingly. Patient response switch is internally connected to AT mega 328. Micro controller saves the patient response and sends the recorded data as a text message to health care unit via SIM 900. By this test we get minimum and maximum hearing frequency.

IV. EXPERIMENTAL SET UP

A. Design of Portable Audiometer:

The design of portable audiometer meets the basic requirements of portable audiometer. It eliminates the extra periferals like laptop, Pc etc.

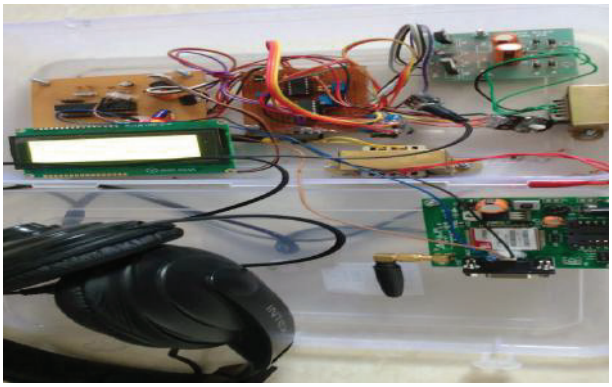


Fig. 4. Hardware setup of proposed Portable Audiometer

The design of proposed system shown in Figure 4. It contains Power supply unit, PCB which contains function generator and audio amplifier circuit, microcontroller, SIM 900, LCD and Headphone

B. Cellular Network Data Communication:

Wireless cellular modem which is capable of notifying a remote healthcare professional is used. SIM 900 is used for simple messaging services. The SMS text message services are carried over low frequency range. Clinician get the text message and interpret the results of hearing test. According to the hearing results medical practitioner can make recommendations.

C. Training:

This system requires little training by an audiologist. Before using this system, patient should trained by audiologist. As follows: 1)choose the quite room for testing; 2) sit and take the device out from the ergonomic packet; 3) plug in the device 4) fix the ear phone to the first ear(left/right); 5) listen the generated signal and respond accordingly by patient response switch; 6) increase/decrease the volume by using the rotatory switch; 7)once first ear testing will done then use the ear phone for another ear of same test object and respond on patient response switch according to the signal.
Patients are able to test their hearing capacity at home as well as clinic with high resolution as the system gives more resolution than existing system. This practice of testing will help to rescue the hearing loss. It will improve their lifestyle.

D. System Specifications:

TABLE I. PROPOSED SYSTEM SPECIFICATIONS

Parameters	Value
Frequency range [Hz]	250 to 8000
Frequency resolution[Hz]	0.1
Intensity range[dB]	0 to 120
Intensity resolution[dB]	0.1

Table I. shows the specifications of proposed system.

E. Comparisons With Commercial Portable Audiometer :

TABLE II. COMPARISONS BETWEEN PROPOSED SYSTEM AND MADSEN ITERA II

Seq. no.		Proposed System	MADSEN ITERA II
1	Frequency range [Hz]	250 to 8000	0.125to 1600
2	Hi resolution freq steps	Yes	No
3	Intensity range[dB]	0 to 120	5 to 125
4	Ambient noise detected	Yes	No
5	Automated capability	Yes	No
6	Remote health capability	Yes	No
7	Size[inches w*h*d]	$12 * 6 * 3$	$17.7 * 11.4 * 3.3$
8	Weight[oz]	32	160

Table II shows the comparisons with commercial portable audiometer. Remote health care facility indicates that audiologist is not needed for the patient to perform the hearing test, patient can test himself at home or clinic. Proposed system not required any peripherals like laptop, PC to perform any task.

V. RESULTS AND DISCUSSION

The system is tested over some patients and results were compared to MADSEN IITRA II audiometer.

A. Frequency and Voltage measurement

The frequency of the waveform generator is a direct function of the DC voltage. By altering this voltage, frequency modulation is performed as shown in figure . The voltage is 10.19 v and the frequency shown in DSO is 2.55Hz. The

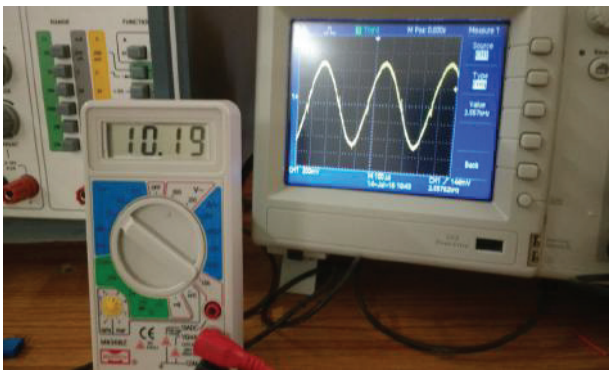


Fig. 5. Accuracy of the attenuator across various level settings.

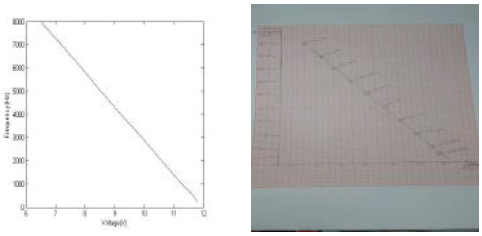
variation in voltage and frequency is linear as shown in table III.

By increasing the voltage, the frequency is decreasing linearly. The voltmeter and DSO is used here for measurement purpose. The linearity graph is shown in figure 6.

By varing the voltage, the frequency is changed so, the patient

TABLE III. FREQUENCY AND VOLTAGE VARIATION

Sr no.	Frequency(Hz)	Voltage(v)
1.	250	11.8
2.	500	11.65
3.	1000	11.28
4.	2000	10.58
5.	3000	9.92
6.	4000	9.22
7.	5000	8.54
8.	6000	7.87
8.	7000	7.20
8.	8000	6.50



(a) Frequency verses Voltage,Linearity (b) Frequency verses Voltage,Linearity

Fig. 6. Linear variation of Frequency and Voltage

will get different frequency by varying the voltage with the help of rotary switch. The audio amplifier is used to amplify the audio signal. By varying the potentiometer in the amplifier circuit the patient can vary the amplitude of the signal. The variation in amplitude is shown in figure

B. Subject testing results

This system was evaluated in both home and hospital ward, to find that this system works properly to determine hearing threshold accurately or not. Subjects were tested in both environments, in which some subjects with normal hearing and remaining with hearing impairment.Table IV shows one patient hearing test result.

TABLE IV. HEARING SCREENING TEST FOR NORMAL HEARING PATIENT

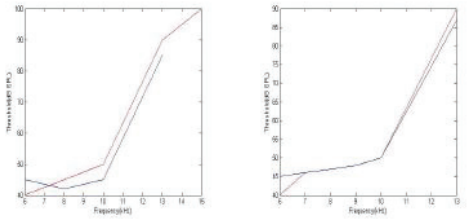
Sr no.	Frequency	Right Ear (I)	Left Ear (I)
1.	250 Hz	5 dB	10 dB
2.	500 Hz	10 dB	7 dB
3.	1000 Hz	4 dB	6 dB
4.	2000 Hz	9 dB	6 dB
5.	4000 Hz	8 dB	5 dB
6.	8000 Hz	7 dB	4 dB

C. Case study of hearing loss identification evaluation

For this evaluation, we select the subject who has complain of hearing. Hearing evaluation done and the graph shows the loss of hearing . The graph shown in figure 7(a). Right ear hearing loss monitoring result and Figure 7(b). Left ear hearing loss monitoring result, tells that the subject's hearing capacity decrease slightly.

D. Remote health care facility

When patient respond on the patient response switch, the response is recorded in micro-controller and text message is send to the mobile number which is fed in micro-controller



(a) Right ear hearing loss monitoring result (b) Left ear hearing loss monitoring result

Fig. 7. Hearing loss monitoring results

as shown in figure.By this the developed system gives remote health care facility.

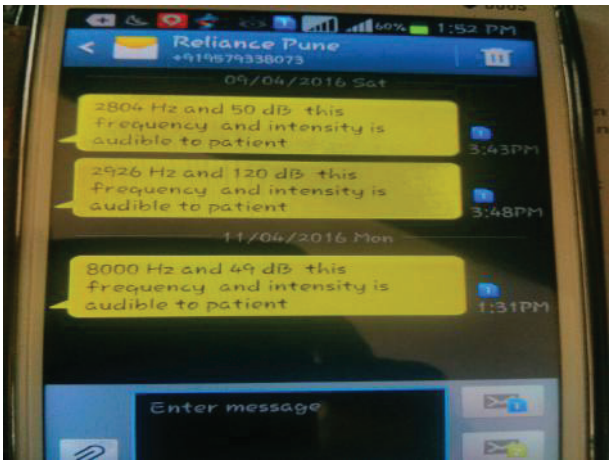


Fig. 8. SMS by using SIM 900

VI. Conclusion

In this paper, we presented the design and evaluation of a portable audiometer which can be used in homes/clinics. This system is capable of evaluating any type of hearing loss, it may be of conductive, hearing sensation of neural and mixed hearing loss. The range of testing frequency is 20 Hz to 20 kHz. From hospital visit; it was learnt that generally hearing test occured at 250Hz to 8kHz. This range covered by this system. This system is capable of store the patient response for remote health care application. The system gives the facility to transmits the patient's response to the health care unit. The system was tested by evaluated on the patient of hearing loss. The testing environment was taken as in home, booth,hospital treatment unit. We found the system to be accurate and reliable. Frequent and regular monitoring of hearing sensitivity can protect the patient from further damage. One who works in heavy machinery plants always in contact of high sound pressure level(SPL), which may affect the hearing sensitivity of that person. By using this system with little training hearing sensitivity easily can be monitored. Future developmental work may include adding other features to improve the ease and accuracy of hearing sensitivity monitoring.

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