Speech Pressure Monitoring Device for Parkinson's Disease

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***Abstract*— Measurement of dynamic tongue and lip pressure is very important as this helps to understand the physiological deviations realistically and helps in quantifying some of the attributes of such deviations such as speech intelligibility issues secondary to neurological causes (e.g., Parkinson's Disease). The skin attachable sensor is the component that is being developed in this work. The system will help the Parkinson Disease patient to get their speech pressure results without going to the laboratory. Here, the condenser microphone is used as the sensor which senses the sound waves falling on the diaphragm. The system is capable of measuring the speech pressure of the patient and assessing the severity level of the disease by comparing the speech pressure values with normal ones.**

***Index Terms*—Parkinson's Disease, Sound Pressure Level, Healthy Controls**

I. INTRODUCTION

Approximately 75% of people with PD have speech and voice characteristics that affect their communication abilities [1]. By examining day-to-day performance through repeated data collection sessions, the magnitude and nature of instability of speech and voice performance exhibited by people with PD can be assessed [2]. Understanding this potential for instability will be important for clinical assessment of people with PD [3]. If large day-to-day fluctuations exist, clinicians may need to consider assessing people with PD on more than one day to ensure accurate sampling of speech and voice performance abilities. Clinical observations of subjects with PD would suggest they have an impaired perception of their own speech and voice abilities [4]. Parkinson's disease (PD), also known as idiopathic parkinsonism, is a neurodegenerative disorder of the central nervous system, which is mainly destroying the substantia nigra [5]. This seriously impairs the secretion of the neurotransmitter dopamine and that in turn affects emotion, cognition as well as autonomous and motor neuronal activity [6]. Thus, if there is a neuronal deficit that is generally causing tremors, then it should affect phonation [7]. Vocal tremor is often defined as an unintentional low-frequency modulation of the vocal fold vibration and the sound pressure of this person will be from 2dB to 40dB lesser than the healthy conditioned person, whereas, the sound pressure of a healthy conditioned person is 50-60 dB or above [8]. There are various devices in the market to detect this disease but they mainly depend on the static voice input, in which the data is processed using only one word and also uses sensors which are kept intraorally to monitor which increases the cost of the device. These devices are language dependent. Considering these aspects, a device is developed that uses dynamic input (continuous speech of the patient) and is language-independent. The sound pressure is monitored which gives accurate data and the device is cost-efficient. The acoustic variable of vocal SPL, as a measure of vocal loudness, is of particular interest.

II. RELATED WORK

Correa et al. [7] proposed an embedded system for the real time analysis of speech from people with Parkinson's disease is presented. Two platforms are developed. First, a Matlab Graphical User Interface is presented; second, the application is deployed in a minicomputer that has an audio codec, storage capacity, and an efficient processing unit. The device has been equipped with an LCD monitor to display the information on real-time, and a mini keyboard for the interface with the user. Different measurements that are commonly used in the assessment of speech from people with PD are evaluated. In agreement with the state of the art, an increment of the pitch variation is shown for patients with PD, additionally, lower values of the vowel space area (VSA) are also shown for speech recordings uttered by people with PD. Michela Borghetti and M. Serpelloni [8] proposed a device that measures tongue pressure on the hard palate directly inside the oral cavity and transmits the data via a wireless link. Since no cable links the pressure sensors inside the oral cavity and the readout unit is located outside of the mouth, this device is low invasive, which represents an important feature for this type of device. The field of application of these devices is the treatment of patients with deglutition and speech disorders or with gnathological (related to the entire chewing apparatus) and dental disturbances. Fox and Ruston et al. [9] discussed a system for self-perception of speech and voice and vocal sound pressure level (SPL) in men and women with idiopathic Parkinson's disease (PD) and in healthy individuals were compared in this study. The data-collecting procedures were repeated by the subjects on three separate days to evaluate performance stability. The findings showed that during speech and voice tasks, patients with PD had vocal SPL (2.0–4.0 dB SPL; 30 cm) that was statistically substantially lower than that of HC subjects. Repeated measurements taken during different sessions showed that PD individuals were not appreciably more unsteady.

III. METHODOLOGY

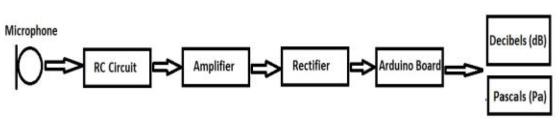

Fig. 1 Block diagram of proposed system

Fig.1 shows the block diagram of the proposed system. The ANSI S1.15-1997 standard (ANSI, 2006) specifies laboratory standard microphones to be of condenser type [10]. The condenser microphone typically has a flatter frequency response. The input is given to a condenser microphone which converts the sound signal to an electrical signal by the metal diaphragm which acts as a back plate. The sensitivity of the microphone determines the measurement precision. Four types of microphones can be used in sound level meters they are piezoelectric type, condenser type, electret, and dynamic type microphone. In this, we have used a condenser microphone because it is more accurate than the other types of microphones which are constructed similarly to a capacitor. A thin membrane or thin metal foil is

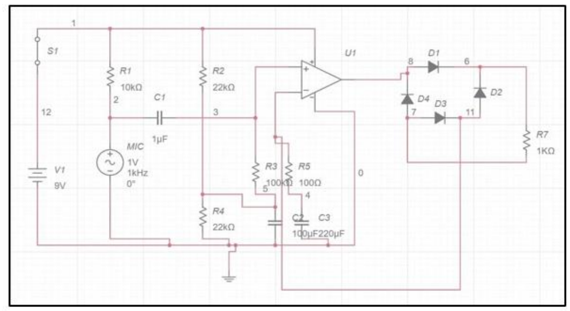

Fig. 2 Circuit Diagram of the Hardware

close to a solid metal plate. The membrane or diaphragm moves back and forth relative to the solid metal plate when sound waves hit the diaphragm. When a sound field excites the diaphragm the capacitance varies according to the variation in sound pressure. Hence, the capacitance changes to the rhythm of the sound and converts it to an electrical signal. A stable DC voltage is applied to the plates through a high resistance to keep electrical charges on a plate. RC circuits are used to filter a signal by blocking certain frequencies and passing others. Fig. 2 shows the circuit diagram of the hardware. The circuit consists of a non-inverting amplifier based on op-amp CA3140 (IC1) which amplifies the voltage through the RC circuit and is rectified by the bridge rectifier. The current at the output that is the voltage measured across the output is proportional to the pressure of sound falling on the microphone. This pressure is displayed on the serial monitor in Pa and dB pressure. A stable DC voltage is applied to the plates through a high resistance to keep electrical charges on a plate. The circuit consists of a non-inverting amplifier based on op-amp CA3140 (IC1) which amplifies the voltage through the RC circuit and is rectified by the bridge rectifier. The current that flows through the 1k resistor is the voltage measured across this resistor is proportional to the pressure of sound falling on the mic. Fig. 3 and Fig. 4 shows the pressure values in dB for HC male and female speech samples respectively, and Fig. 5 and Fig. 6 shows pressure values for PD male and female speech samples. It is observed that there is a significant difference in the pressure values of PD samples than the HC samples. Pressure for PD subjects is lower than pressure values for HC's. This pressure is displayed on the serial monitor in Pa and dB. Hence, this device will measure the continuous speech pressure without measuring intraorally.

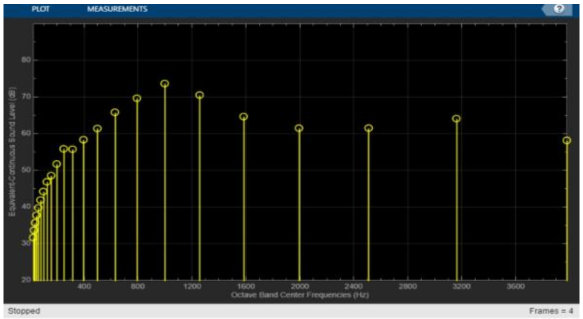

Fig. 3 Pressure in dB for HC male speech sample

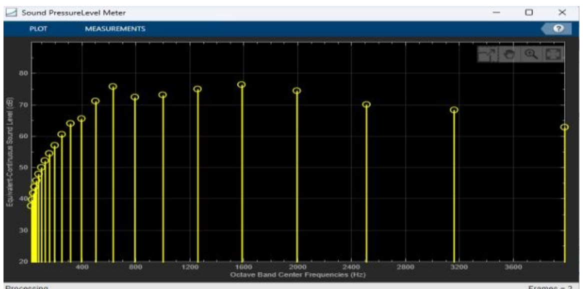

Fig. 4 Pressure in dB for HC female speech sample

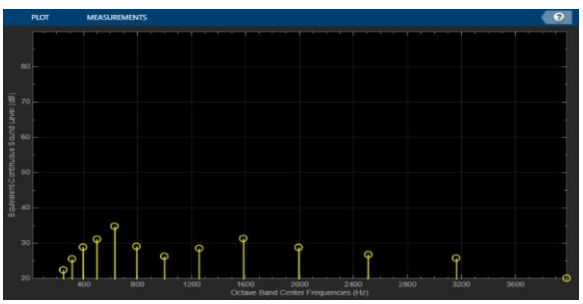

Fig. 5 Pressure in dB for PD male speech sample

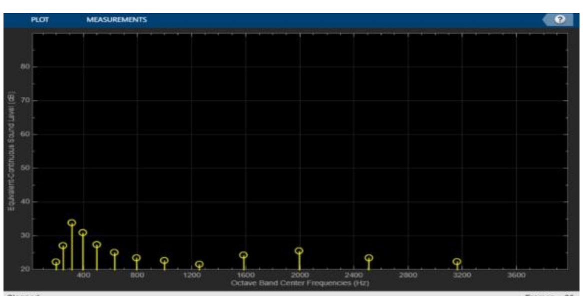

Fig. 6 Pressure in dB for PD female speech sample

The microphone is placed 30 cm in front of the subject's lips and maintained at that distance throughout the session because this position is recommended by the Union of European Phoneticians for stand-mounted microphones [10]. 40dB is the softest phonation that is recorded from the simulation at a 30cm distance. The noise level must be less than a signal to the noise level at a 30cm distance for proper interception of sound by the microphone (15dB). An environment that is not soundproof can have levels of more than 40dB which evaluates the softest phonation is more problematic. The condenser transducers are powered by a battery of 9V. Even if there is a small change in the position of the microphone placement to the mouth there can be changes in the measurement of SPL which are non-negligible. The issue is about the placement of the microphone which needs to be taken care of. The recordings should be made ideally in a sound-treated room, but a quiet room with ambient noise < 50 dB is acceptable [11][12].

IV. RESULTS AND DISCUSSION

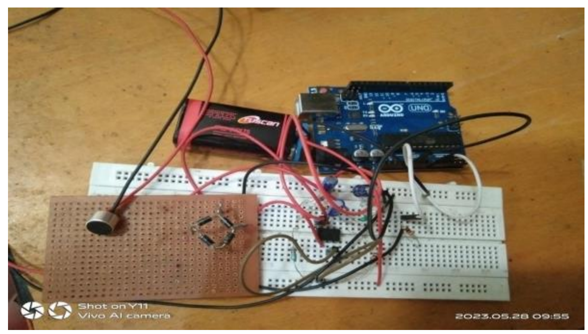

Fig. 7 Hardware Implementation

Fig. 7 shows the hardware implementation of the proposed work. The subjects were instructed to say 'ah' as long as they could in the microphone. For a long sustained phonation, the subjects were instructed to take a deep breath before phonation and there were no instructions for loudness.

Table I Public audio data analysis of mean SPL in dB for sustained vowel phonation 'ah'

Type of Subject	No. of Subjects	Mean SPL (dB)
PD Male	80	30.00
PD Female	72	27.05
HC Male	22	55.19
HC Female	39	56.11

From Table 1 the mean value of the PD subject's SPL for males is 35dB less than the HC subject's SPL mean value and is comparable with PD female subjects mean SPL. The female PD subject's mean SPL is about 38dB less than HC subject's mean SPL value. The PD subjects have SPL value at a range of 30-

55dB. Similar to PD subjects, HC subjects have comparable mean SPL between its male and female subjects. The SPL value of the HC subjects varies from 50-65dB.

V. CONCLUSION AND FUTURE SCOPE

The running continuous speech pressure can be measured through the sensor because of its continuous capacitive effect. The sensor senses the sound pressure that falls on the microphone. The capacitance change due to the sound waves produces a continuous voltage that can be filtered, amplified, and rectified and is measured for pressure. The circuit measures the pressure instantly. It is easy for the patient because it does not depend on the language that the person speaks. Hence, this circuit can measure the pressure of the continuous speech instantly. The greatest difference in vocal SPL between subjects with PD and HC subjects was observed on the maximum sustained vowel phonation task. Sex did not play a significant role in differences in vocal SPL. Repeated phonation is required for stability in measurement on a day-to-day basis. The monitoring should be made ideally in a sound-treated room, but a quiet room with ambient noise < 50 dB is acceptable.

The future scope of this system is to make the device portable instead of using a laptop to observe the result. Developing an app to help the user observe the results on their phone itself. The system will help the PD patients to get their speech pressure results without going to the laboratory.

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