Abstract—The affordability of the medical diagnostics is going high over time. To overcome this scenario people are looking for inexpensive, reliable and effective healthcare technologies that are user-friendly and could be used in home without physicians help. This paper focuses on the design and development of low cost Abductor digiti minimi (ADM) muscle monitoring system using surface electromyography (sEMG) that detects the electrical pulses from muscle and transmitted wirelessly. Telemedicine is one of the rapidly developing field’s nowadays; hence remote monitoring plays a vital role in faster diagnosis by which continuous monitoring is carried out using ZigBee – wireless technique. The EMG data obtained in the receiver end is analyzed using MATLAB software.

Index Terms—Telemedicine, Zigbee, MATLAB

I. INTRODUCTION

Of late, biomedical engineering research is focusing on the development of affordable healthcare equipment that are reliable, portable and easily available in the market. As per the literature conducted, the muscle abnormalities are increasing at a rapid rate over a period of time [1]. With increase in cost of medical diagnostics, there arises a need for affordable equipment. One such equipment is Electromyograph (EMG), as it is least available and of high cost in Indian market. The lack of physicians and the need for medical help in remote places has increased its growth. In Telemedicine, networking plays an important role which acts as a bridge between the doctor and a remote patient. This paper deals with implementation on ZigBee technique in EMG, which detects and records the electrical signals during muscle contractions. The EMG examination has greater sensitivity and specificity for investigating the location and distribution of the neural pathways that act as the mode of nerve fibers involved [2]. Muscle membrane generates an electrical potential of 50uV to 30mV depending on the muscle type and conditions during the observation process. The usable energy of the signal is limited to the 0 to 500 Hz frequency range, with the dominant energy being in the 50-150 Hz range.

There are many muscle groups in human body, among them ADM muscle in palm as shown in Fig. 1, plays an important role in our day to day activities [3]. ADM is a skeletal muscle that arises from the pisiform bone, the pisohamate ligament and the flexor retinaculum and present on the ulnar border of the palm and it helps in pulling the little finger away from rest of the fingers in hand and also helps in grasping large objects with outspread fingers.

Figure 1. Abductor Digiti Minimi muscle.

There are many manufacturers of EMG of which some of the notable companies are Natus, Gymna, Contec and Laborie [4]. The overall EMG signal acquisition product prices ranges between USD 3,000 and 10,000 approximately. In general a data acquisition system (DAQ) is used to carry out this work, which is of high cost. This system uses a PIC16F877A microcontroller that has an inbuilt analog to digital conversion and then the data is transmitted serially through ZigBee to the remote place. The received data is analyzed using MATLAB, which is a programming language that allows the user to monitor and control the parameters more easily.
II. SYSTEM DESIGN

The block diagram shown in Fig. 2 depicts the working model of developed system. The electrical pulses from the muscle are sensed by the electrodes and the voltage difference of detected signal is amplified with the help of Instrumentation amplifier. The noise in the amplified signal is filtered using a band pass filter then converted to digital and transmitted through ZigBee via microcontroller.

![System block diagram](image)

A. Electrodes

The placement of Electrodes plays a vital role in acquisition of the signal. The primary sensing element used in the system is a non-invasive button like electrode made of Ag. – Ag.cl of 10 mm diameter is firmly placed at a point midway between pisiform and ulnar aspect of the fifth metacarpophalangeal joint and another is placed at approximately 2 cm apart on the ADM muscle to obtain the differential voltage [5].

B. Signal Conditioning

The electrical pulses from the muscle are sensed by the electrodes amplified using instrumentation amplifier. In general AD620, INA126 are used in this paper LM324 [6] is chosen as it is of low cost. It consists of four independent high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single supply over a wide range of voltages.

The noise in the signal is filtered using an active filter which improves the performance and predictability [7]. The usable range of EMG signal is in between 50 Hz and 150 Hz, hence to acquire the desired frequency range a second order Butterworth band pass filter is being used as it provides the flattest amplitude response. Both the Low pass filter and High pass filter form a Band pass filter which ultimately allows an EMG signal in between the required frequency range [8].

The analog output obtained from the signal conditioning circuit is given to the microcontroller – PIC16F877A [9] supports USART communication. It requires an external crystal of 10 MHz to trigger the in-built oscillator. The source code will be written in the C language using MPLAB IDE program. The digital output taken from the port of the controller is given to transmit and receive pins of MAX232 for level conversion.

C. ZigBee Module and PC Integration Board

ZigBee is a technological standard, based on the IEEE 802.15.4 standard, which was created specifically for control and sensor networks ideal for the implementation of a wide range of low cost, low power and reliable control and monitoring applications within the private home and industrial environment. The wireless transmission of data using ZigBee requires one XBee chip as shown in Fig. 3 (a) and a USB development board (Fig. 3 (b)) on the transmission side and one XBee chip and a serial/USB board at the receiving side as given in Fig. 3 (c).

The ZigBee module can transmit data in the range of 30m to 100m. It supports Analog-to-Digital conversion and Digital I/O line passing. Advanced configurations can be implemented using simple AT commands or API. The received data can be viewed in hyper terminal or the terminal window of the X-CTU software. Fig. 3 (d) shows the PC integration board used in the system developed.

![ZigBee module and PC integration board](image)

D. Software Section

The software used in this paper is MPLAB IDE which is new graphical, integrated debugging toolset for development of embedded applications on Microchip’s microcontrollers [10]. To write the code in C language MPLAB C compiler is chosen. The main function of the MPLAB compiler in transmitter side is to convert the
code to a HEX file and then sends to the COM port in digital format (Fig. 4(a)). In receiver side MATLAB compiler is used to write a code to design software that is used to receive the data from the COM port and transmits it wirelessly to display it on computer. Data is acquired to computer from the controller using Silicon lab’s IC CP2102 [11]. The transmitted information is in ASCII characters and the software receives the data at the COM port and then it does the necessary decoding and the data is displayed in the data section in the software. The Baud Rate, COM port number, Parity, Start Stop bit, handshaking modes and a number of additional features are supported by the system. The Asynchronous mode of data transmission was chosen as there is no need of a serial clock and this effectively extends the range up to which the signals can be transmitted. The flowchart shown in Fig. 4(b) shows the process involved in serial data transmission and reception.

**TABLE I. COMPARISON RESULTS OF COMMERCIAL WITH PROPOSED EMG**

<table>
<thead>
<tr>
<th></th>
<th>No load</th>
<th>Isometric condition</th>
<th>Isotonic condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Commercial EMG</strong></td>
<td>42.308</td>
<td>52.983</td>
<td>111.96</td>
</tr>
<tr>
<td><strong>Proposed EMG</strong></td>
<td>39.85</td>
<td>49.57</td>
<td>110.5</td>
</tr>
<tr>
<td><strong>Commercial EMG</strong></td>
<td>30.773</td>
<td>45.866</td>
<td>87.079</td>
</tr>
<tr>
<td><strong>Proposed EMG</strong></td>
<td>31.85</td>
<td>44.75</td>
<td>80.45</td>
</tr>
<tr>
<td><strong>Commercial EMG</strong></td>
<td>31.390</td>
<td>46.870</td>
<td>96.000</td>
</tr>
<tr>
<td><strong>Proposed EMG</strong></td>
<td>26.57</td>
<td>40.85</td>
<td>97.57</td>
</tr>
</tbody>
</table>

For three different subjects under three different conditions values are taken for several times, average of 10% of deviation is found in the proposed EMG with the commercial one. This error can be sorted by proper signal conditioning circuit. For ease of analysis the data is further represented in the form of a graph as shown in the Fig. 6. The output of the entire system can be viewed on the software that is developed using MATLAB compiler which acquires the data from the COM port and transmits through ZigBee and displays on the PC. The

**III. EXPERIMENTAL SETUP AND RESULT ANALYSIS**

The instrument designed (Fig. 5) is used to extract myosignal against strain to study ADM muscle behavior under three different conditions 1. No Load 2. Isometric condition (load of 100 gm is applied at the end of little finger with the help of a spring balance) 3. Isotonic (Maximum strain) - probably for the first time - is inexpensive.

EMG signal acquired from different subjects is filtered and processed to extract root mean square value and compared with commercially available EMG instrument from Clarity Medicals as indicated in Table I.
communication is done using COM port and USB protocol. The final result is as shown in Fig. 7.

![Software output for Strain Vs Voltage](image)

**Figure 7.** Software output for Strain Vs Voltage

### IV. CONCLUSION

The proposed instrument is thus inexpensive, affordable, reliable, easily transportable and accurate when compared it with the commercially available Electromyography instrument. Therefore the goal to develop a low cost EMG system which is beneficial to research group is an advantage for the patient and physiotherapies. This study aims to design the sEMG that can be applied to the ADM muscle, by time and frequency domain analysis; the RMS value of EMG signal can be estimated. The effectiveness of the design was evaluated in the experiment and should be improved.

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### REFERENCES


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