

Body Composition Analysis using Bioimpedance Measurement Technique

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ABSTRACT: Specified range of various body content should be maintained in order to function body in neat and proper condition. Body also requires some fats to become healthier. It is utmost important for different basic body functions such as storage of the vitamins, organs/joints softening and body temperature maintenance, also too much fat can also damage your health. It can also create serious health related conditions which will put us at higher risk. Non-invasive methods and technique for detection is now fundamental need in biomedical field and health care systems. Bio-Impedance Measurement System is emerging technology which is suitable technique for tissue level diagnosis. The proposed system describes a non-invasive technique for evaluation of body composition by using bio-electrical impedance analysis by applying voltage-current pulse technique. Two electrodes are used for measurement of bio-impedance. The potential across biological tissues is measured and voltage spectrum is acquired in MATLAB using FFT which is used to find the value of bioimpedance. By using the results of bio-impedance, total body water, fat free mass and fat mass are evaluated and estimated. This kind of analysis can be performed using number of persons of different age groups and different body weights. The final medical report of the patient can be created and the result shows the current status of the patient's health depending on the value of his body fats.

KEYWORDS: Bioelectrical Impedance, Body Fat Percentage, Impedance Spectroscopy, Non-invasive Bio-sensing, TBW.

I. INTRODUCTION

For intermittent and continuous or even contactless devices such as wearable, wireless and distant biomedical sensing required call to be made to Pervasive healthcare [1]. For the preventive measurement, healthy people are also considered in this system. This is the main reason why non invasive sensor becomes popular. Optical spectroscopy, ultrasound, magnetic resonance imaging and X-ray are some of the different popular noninvasive techniques. By illuminating the portion of the subject under test, these techniques measure the bio-sensing and also measure the effect of absorption or transmittance or reflection [2]. These techniques provide basic level information on proton density distribution or mass. This technique offers many advantages over traditional methods. Some of the key advantages are noninvasiveness, reasonable cost, applicability and capability to perform online monitoring [3, 4] for measuring the conductivity and permittivity.

In biomedical sensing, bioimpedance spectroscopy allows to calculate impedance. Some of the examples are finding the fatty tissues, various kind of cancer detection which measures tissue impedance at zero frequency. Many frequency stimulations are applied for measuring the body impedance using Bio-electrical Impedance Spectroscopy techniques. The study of BIS shows its importance for the applications of body fluid measurement [7, 8]. Body fluid applications are used to frame estimates for intra/inter/extra cellular fluids and total body water [5, 6]. Depending on the characteristics and structure the electrical properties of biological tissues may differ significantly. These kinds of variations are used to distinguish benign cells using Electrical Impedance Tomography (EIT).

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The proposed work is being used to present a non-invasive technique for calculation of body composition using bioelectrical impedance analysis by using voltage-current pulse technique. Two electrodes are used for measurement of bio-impedance. Once the potential across biological tissue is measured, voltage spectrum is found. Voltage spectrum found in MATLAB by using FFT. The result of FFT is used to find the value of bio-impedance. Further using these results of bio-impedance, Total Body Water, Fat Mass and Fat Free Mass are estimated. The final medical report of the patient is then generated which includes fat mass, total body water, fat free mass, body fat percentage and also the overall status of health.

II. RELATED WORK

Bio-impedance technique is introduced with bioelectrical impedance analysis. This type of technique is developed gradually into bio-electrical Impedance Spectroscopy (BIS) [10]. Term BIS is also expanded as multiple frequency bioelectrical impedance analysis [9]. Bioimpedance analysis has many advantages like non-invasiveness, less measurement cost and a commonly used technology for measuring body composition and inspection of clinical conditions. There are a variety of methodologies available for bioimpedance calculation of tissues that may predict the clinical status [11]. The bioimpedance signal depends upon many factors like frequency of measurement, placement of electrodes, position of object while taking measurement also the number of electrodes may give the different value of bio-impedance signal. Often these values used for prediction of various body compositions, which are dependent on gender, influence of anthropometric measurements, ethnic groups, measurements protocols, postures etc.

Body composition measurement has many methods which can be used according to the suitable conditions. For various age groups the analysis of body composition can be done and the methods of measurements can be compared. In measuring the body fat the BIA technique is widely used technique. Among all the measurement techniques, body mass index and tricep skinfold thickness method are very simple methods which indirectly calculates the body fat. So these methods are generally preferred for measuring childhood obesity. BIA is a useful and alternative method for detecting body composition and may be a more precise tool than skinfold measurement method for measuring FM [12].

III. METHODOLOGY

Electrical circuit equivalent to the human biological cell is shown in Figure 1.

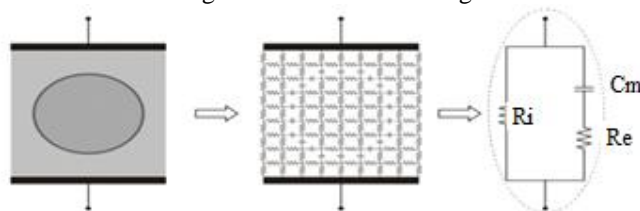


Fig. 1. Equivalent Circuit for Biological Cells

It consists of resistance of extra-cellular medium, resistance due to intra-cellular medium and cell membrane capacitance. Electrical current will flow in each case through the biological cells or through the extracellular medium. We can classify the current through the cells as the current from the membrane between intracellular fluid and extracellular fluid which is also called as trans-membrane ionic channel or plasma membrane. Dielectric properties are shown by cell membrane. However R_e and R_i are used to represent the intra-cellular medium and extracellular medium resistive behavior [2].

Proposed work is based on electrical impedance spectroscopy of voltage-current pulse technique for measuring bioelectrical impedance. Injection of a current pulse for shorter duration will give the complete frequency response of biological tissues. Discrete pulse obtained from response contains all frequency components. Any distortion in voltage pulse is used to detect the frequency behavior and it is explained by the electrical behavior of the biological

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tissues. It is recommended to pass the current pulse for time duration until resulting voltage is stable. Stability in voltage means that C_m is completely charged.

IV. BIOIMPEDANCE MEASUREMENT SYSTEM

Impedance measurement is achieved in two sections which consist of injection of current in biological tissue, detection of voltage change in tissue and impedance estimation.

The first section involves three major parts of impedance measurement system as follows:

- Current source
- Detection of voltage
- Processing on measured potential and sending it to PC for further processing.

The second section involves the software to calculate impedance and evaluation of various body compositions.

The implementation of the proposed work is described by Figure 2. The power supply module has the three different circuits for generating 3.3V, 5V and 12V of supply which is required for different circuit. We are using bipolar method for bio-impedance measurement so it is having two electrodes, one of which is used for the injection of current in the human body and second one is for the detection of the change in potential. The instrumentation amplifier is used for signal conditioning. LCD is used for displaying the potential changes recorded by the bio-impedance measurement circuit.

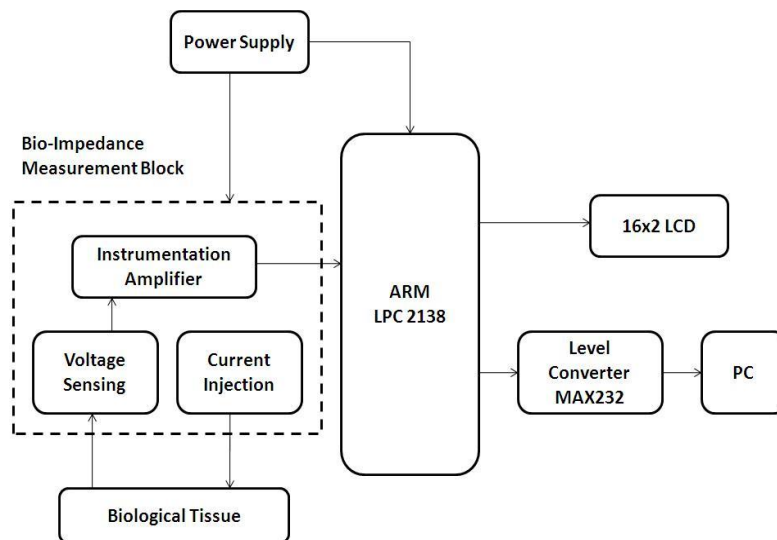


Fig. 2. Proposed Block diagram for body composition measurement

The hardware setup made for this arrangement is shown in Figure 3. Two electrodes are used for injecting the current and sensing the potential changes. Once we measure the potential changes the values are sent to PC for further processing.

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Fig. 3. Experimental Setup

V. GENERATION OF CURRENT PULSE AND DETECTION OF VOLTAGE

Irrespective of the load variation, current value should be stable for impedance measurement system. In pulse based impedance measurement systems tetra-polar measurement system is used in which four electrodes are used. Two electrodes used for injecting current in body and two are for detecting potential variation from body. Proposed work implemented bipolar method in which two electrode arrangement is used for both purpose as for current injection and voltage detection in order to reduce tissue irritation due to polarization.

According to the virtual ground phenomenon, current injection is done by using two electrodes A and B. The voltage detection is done across measuring electrode A with respect to ground. This would be equivalent to voltage across points A and B. Two electrode setup for voltage detection is thus possible.

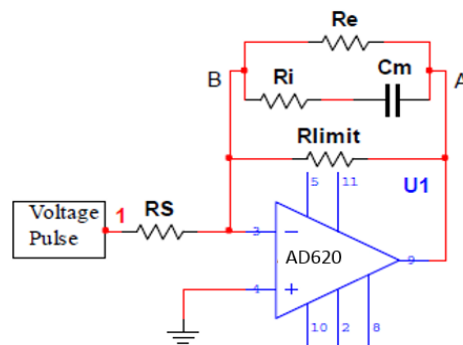


Fig. 4. Voltage Detection Circuit

VI. IMPEDANCE ANALYSIS AND BODY COMPOSITION MEASUREMENT

Biomedical sensors generally have common mode noise issue. For implementing and estimating the system which can efficiently measure bio-medical electrical signal information, the designing of amplifiers with high differential gain and high CMRR is very important. The instrumentation amplifier is used with the common mode rejection performance. Finally, the change in potential is acquired using ADC and serial port interfacing in the MATLAB R2008a and Visual Basic for processing and estimation of bioelectrical impedance and body parameters.

Once the potential across bio-logical tissue is fetched and recorded, voltage spectrum is found from which FFT is calculated in MATLAB. Least curve fitting method is used for the estimation of impedance value. Using this procedure we calculated real and imaginary values of the impedance. Considering the person's age, sex, weight, height, the various body parameters are measured by using estimated impedance values. We calculate fat Mass, Fat Free Mass,

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Total Body water Content and Body Fat Percentage. FFM and FM are calculated with the help of TBW using Equations (1), (2) and (3) respectively [2].

$$(1) \quad TBW \text{ (Liters)} = \left(a * \frac{HEIGHT^2}{I} \right) + (b * SEX) + (c * WEIGHT) - (d * AGE) \square \square \square \square \square$$

$$FFM = \frac{TBW}{0.732} \quad (2)$$

$$FM = BW - FFM \quad (3)$$

Where, a = 0.372, b = 3.05, c = 0.142, d = 0.069, Height in centimeter, I = Impedance of Body, Sex Male = 1, Female = 0, Weight in Kilogram, Age in Years, BW is body weight in kg.

VII. EXPERIMENTAL RESULTS

We obtained the potential across bio-logical tissues. All the values are taken as a dataset for calculating the impedance. The values are fetched until we got approximately stable readings. The graph of data set for one reading is shown in Figure 5.

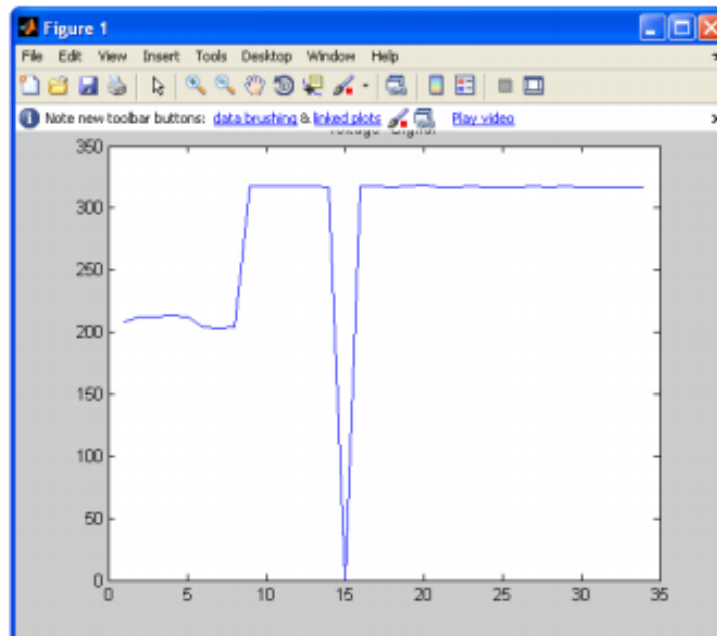


Fig. 5. Body Potential Data Set

Voltage spectrum is found using FFT in MATLAB. The least square curve fitting method is used for the estimation of impedance value. Using this procedure we calculate real and imaginary part of the impedance. The estimation of these values in MATLAB is shown in Figure 6.

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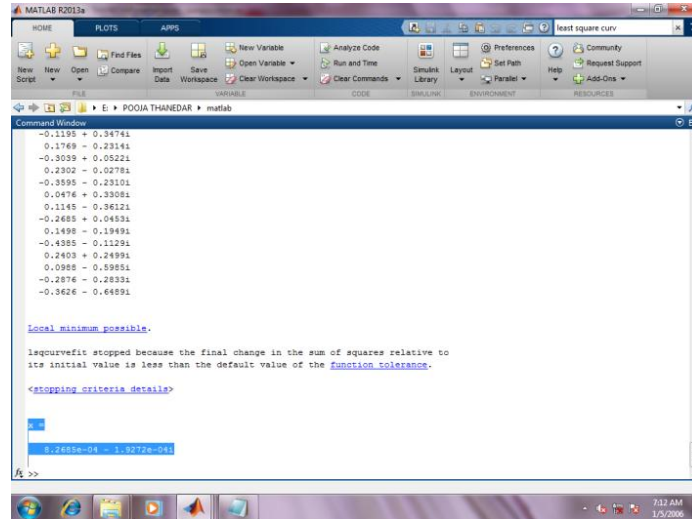


Fig. 6. Evaluation of real and imaginary values in MATLAB

Electrical impedance is successfully estimated with this proposed method. Further using these values, and considering the persons age, sex, weight, height, and the various body parameters are measured. The parameters like fat Mass, Fat Free Mass, Total Body water Content and Body Fat Percentage are calculated and the results are displayed in Visual Basic. The following Figure 7 shows the calculation of all the parameters.

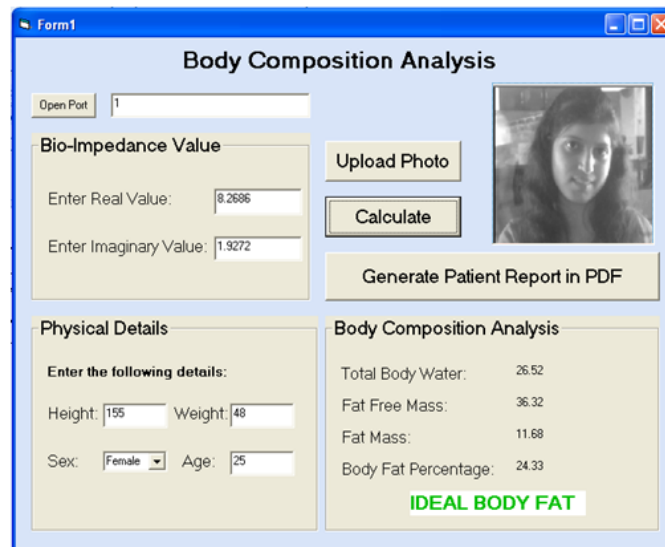


Fig. 7. Evaluation of Body Composition

We also generate the overall body composition report of a patient in PDF file format which contains all the personal details, measured parameters and the status of health depending upon his calculated body composition values by comparing it with standard compositions required for a person to be healthy.

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VIII. CONCLUSION

In this proposed work, we designed the system which is able to measure the bioelectrical impedance. Appropriate signal processing for impedance estimation from impedance spectroscopy is modeled based on least square curve fitting technique

Using this method various parameters are evaluated such as fat Mass, Fat Free Mass, Total Body water Content and Body Fat Percentage. The method of calculating body composition is non-invasive technique and requires less time to obtain the reports.

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