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RESEARCH ARTICLE

# Multi-frequency Measurement of Electrical Bio impedance of Bone to assess Bone Mineral Density

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***Abstract— The design and implementation of an instrument capable of simultaneously measuring bioimpedance at three different frequencies at a reasonable cost required a novel approach to assess the bone quality. A microampere-level sinusoidal excitation current generator operating at frequencies from 100 Hz to 5 MHz are multiplexed to external electrodes on a leg bone, while impedance signals from pair of electrodes are processed within the instrument. 16-bitA/D converters digitize the analog signal, followed by detection using an original method of non-uniform synchronous under sampling. Instrumentation control, data acquisition and display software were developed in the LabView 7.1 VI environment. This is useful for model development, planning of experiments and for training. The instrument will also be used to assess osteoporosis.***

***Key Terms: - Bioimpedance; multi frequency measurement; BMD***

## I. INTRODUCTION

Analysis of Electrical Bio Impedance (EBI) of organs and tissues at several frequencies simultaneously has the potential to increase the value of EBI based monitoring methods [1, 2, 3]. Interest in the EBI based approach has been stimulated by the fact that measurements are either truly non-invasive or at most, minimally invasive. The bone and other organs, as well as the entire cardiovascular and respiratory system, may be monitored *in vivo* by electrodes positioned transvenously [1].

The principal behind this measurement is that electricity flows differently through fat and lean body mass. By measuring the resistance to the flow of a very small current of electricity through different parts of your body (most commonly the arms, legs or both), body fat percentage is estimated. The problem is that many of these devices don't measure belly fat, which is the most dangerous. So if a man has thin legs and a big belly, their body fat measurement will not be accurate. In addition, as with all body composition testing devices, they are sensitive to hydration status. So if you measure your body fat after a workout (when most people are dehydrated) or first thing in the morning, the test will be less accurate and will overestimate your body fat. The most accurate time of day for testing with these units (and any other body composition testing methods) is late morning and before you exercise. Hydration levels may also be affected by excess alcohol intake, medication, and PMS.

The benefits of this testing method are that many of these scales are very inexpensive, do not require special training, and can provide a fairly good week-to-week comparison as long as measurements are done the same time of day and not after exercise. If accuracy is critical, you may want to consider tracking down a more accurate impedance device. GE Healthcare's In Body bio-impedance products are one of the only devices that measure leg, arm and belly fat.

Dynamic variations of EBI can have much more complicated character at significantly different frequencies in comparison with the basal full impedance *Z* (magnitude or modulus), which itself may not vary greatly with the frequency. Commonly EBI is measured using a current source to drive excitation current *I* through the tissue of interest between a particular pair of electrodes. The potential difference *V* generated by the excitation current is sensed by a different pair of electrodes. The complex value of the impedance of tissue between the sense electrodes $\dot{Z}=R+jX$ can be calculated as $\dot{Z} = V/I$.

## II. MATERIALS AND METHODS

In order to study the impedance and change regulation of the electrodes used in the bioelectricity measurement, an electrode impedance measurement and the data acquisition system has developed. A software platform has also been developed to calculate electrode impedance value and dynamically monitor the impedance change. The system can realize real time data acquisition and preservation, display the regulation of data change for particular time duration. The range of the impedance measurement is 500ohms The frequency of AC excitation current in the electrode impedance measurement of the study is.

The system includes a sine wave excitation current generator, operating at different frequencies from 100 Hz to 5 MHz. The excitation generators have differential outputs. Excitation levels, frequencies and phases are digitally controllable from a personal computer, PC, via a USB interface by means of virtual instrumentation software operating in the LabView 7.1 virtual instrumentation (*VI*) environment. Selectors under computer control connect the excitation generators and sense amplifiers to the sample (i.e. patient, organ, tissue). Excitation current generators are connected to electrodes in the sample understudy by the PC controllable excitation selector.

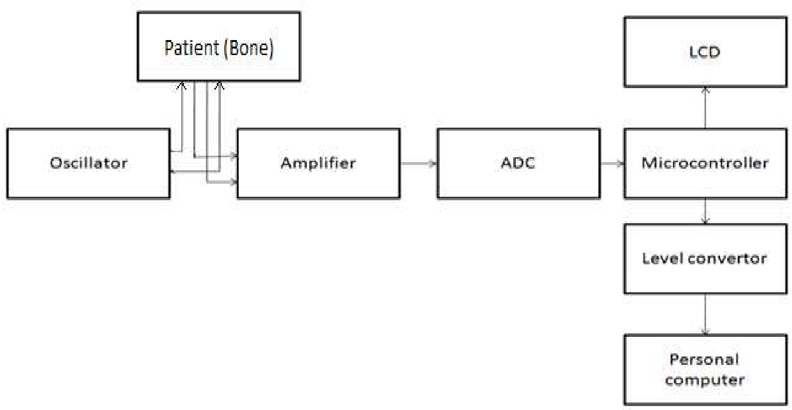


Fig.1. Architecture of the multi-frequency EBI measurement system

Electrical potentials generated by the excitation currents are input to differential amplifier under computer control through a sense selector. Since electrode selection is under computer control, different sets of electrodes may be selected at any phase of the study. The configuration may be static for part of a protocol and may be dynamic with continuous multiplexing during a different phase. It is thus possible to acquire measurements from many more pairs of electrodes than the four available channels in the course of an experiment. Since a sample rate per channel of 30 – 40 Hz is sufficient for hard tissue bioimpedance signals, the instrument can monitor dynamic bone impedance simultaneously for a large number of electrode pairs. The sensed voltages are amplified by amplifiers and digitized using analog-to-digital converters. Digitized signals are processed with a microcontroller.

 

## III. RESULTS

The following window shows the VI program and the corresponding front panel display.

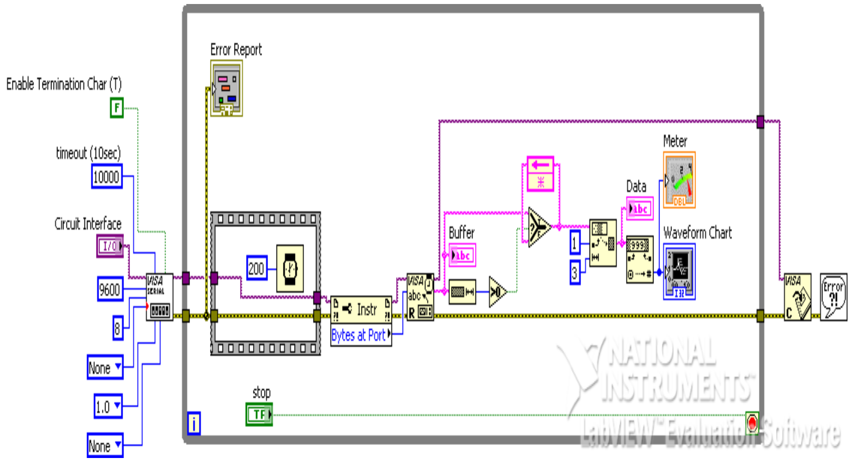


Fig.2. Block diagram using lab view software

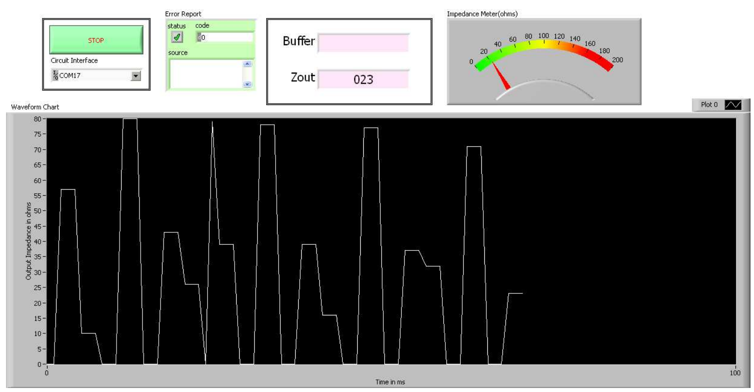


Fig.3. Typical output (front panel) setup

| SUBJECT | FREQUENCY (1000kHz) | IMPEDANCE OF BONE(Ω) (Male-15-20yrs.) | IMPEDANCE OF BONE(Ω) (Female-15-20yrs.) |
|---|---|---|---|
| **Lean Subject** | **18.43<br>962.2<br>1.1** | **65<br>312<br>37** | **85<br>403<br>51** |
| **Medium Weighed Subject** | **18<br>968<br>1.2** | **56<br>230<br>35** | **80<br>311<br>63** |
| **Fat Subject** | **17.8<br>961<br>1.2** | **52<br>200<br>35** | **73<br>216<br>66** |

Table 1. Bone Resistance measurement of different subjects for different frequencies

 

## IV. DISCUSSION

The obtained result shows that the resistance values of men and women subjects under different age groups are changes significantly. Also the weight of the subjects has significant impact on the impedance values. This study can help to assess the bone quality in terms of the resistance. The excitation frequency and the impedance value have directly proportional relationship to the resistance values. Moreover the impedance value is more for women when compared to men under the age group from 15 to 20 years.

## V. CONCLUSIONS

The results of this paper shows that bioimpedance of bone can be measured by electrical excitation of bone using electrodes at different frequencies. According to the property of bioelectric impedance measurement, it is an important initiative to research on BMD assessment. In this study, data were collected only from few subjects. By collecting more no. of data from normal and abnormal subjects, the strong conclusion may be arrived. Bioimpedance can also be measured from various channels by connecting multiple excitation generators.

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