A general view of Electrical impedance tomography in varieties of applications

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Abstract

Electrical impedance tomography is a technique in which image is constructed from the electrical properties of an object. This paper gives an idea of how to present a electrical impedance tomography system that takes image of the electrical conductivity distribution within an object. The importance of electrical impedance tomography is such that it can be used to take an image of internal part of an object. While the object can be the human body part over which electrodes can be attached to take an image of object that gives an internal mechanism of that object in the form of image. EIT has been used in a number of applications, for example in physiological processes involving movement of conductive fluids and gasses, in geophysics and environmental science for locating underground minerals and deposits and for monitoring flow of fluids in to the earth for the purpose of extraction of oil ,non destructive testing of material and in military application such as imaging of buried landmines and in medical diagnosis for example lung ,blood circulation functions, the amount of body moisture, the amount of body fat, breast cancer, etc. This paper gives a view of how to govern electrical impedance tomography, which represents a process used to inject a current and to measure spatial voltage across the object. Thus we get impedance value from which image can be constructed. An open source software, EIDORS (Electrical Impedance and Diffuse Optics Reconstruction Software) was used for image reconstruction. The currents are applied simultaneously to all the electrodes. A number of current patterns are applied, where each pattern defines the current for each electrode, and the subsequent electrode voltages are measured to generate the data required for image reconstruction. A ring of electrodes may be placed in a single plane around the object, to define a two-dimensional problem, or in several layers of such rings, to define a three-dimensional problem. The reconstruction algorithms are a one-step, two-dimensional (2-D) New-ton-Raphson algorithm and a one-step, full three dimensional (3-D) reconstructor. EIT can be used for organs of interest within the image is reconstructed which can be used in medical diagnosis.

1. Introduction

Electrical Impedance Tomography (EIT) is a noninvasive technology to detect human body physiological and pathological information. Its theoretical basis lies in different electrical properties of tissues and organs in human body. It is often realized by injecting current to electrodes on image object and measuring voltage through electrodes [1]. EIT has advantage in noninvasiveness, functional imaging and image monitoring. Electrical impedance tomography (EIT) is a non invasive imaging method that attempts to calculate the internal electrical conductivity distribution from applied current and voltage measurement around the medium of interest.

Electrical impedance tomography (EIT) is a relatively young imaging technique begun in the early eighties which may provide an inexpensive and flexible supplement to existing cryosurgical monitoring techniques [5]. Just as computed tomography, ultrasound, and MRI map X-ray attenuation, acoustic impedance, and nuclear spin phenomena, respectively.

EIT problem is particularly attractive in many important applications such as medical imaging, non-destructive testing of materials, environmental cleaning and geophysics because of its low cost, high speed, and lack of radiation.

EIT relies on differences in bio-electrical attributes within the body to produce an image [7]. EIT, despite its typically limited spatial resolution, offers portability, fast image acquisition, and no dosage concerns in a comparatively inexpensive technology. A typical EIT image is acquired by injecting small sinusoidal electrical currents into the body and measuring the resulting voltages through an electrode array. An impedance image is then produced from the voltage and current data using a reconstruction algorithm [7]. Bio-electrical impedance is generally a function of cell and tissue structure, water and fat content, tissue salinity, temperature, and phase (frozen or unfrozen) [5]. In an effort to obtain more precise evaluations of tissues for diagnostic purposes, bio-impedance measurements can be focused on specific local tissues such as tumors, mammary glands and subcutaneous tissues . Most importantly tissue impedance at zero frequency, corresponding to extra cellular resistances is particularly useful for evaluating mammary glands, lung cancers and fatty tissues. In comparison with x-ray images, ultrasonic images and magnetic resonance imaging (MRI), electrical impedance measurement is inexpensive[6]. At presence, density information obtained by such as Ultrasonic imaging X-CT and MRI are well used for medical tissue diagnosis. However, the EIT is considered very useful clinically because structures, physiological function, and physiological state [6].

2. Concept of EIT

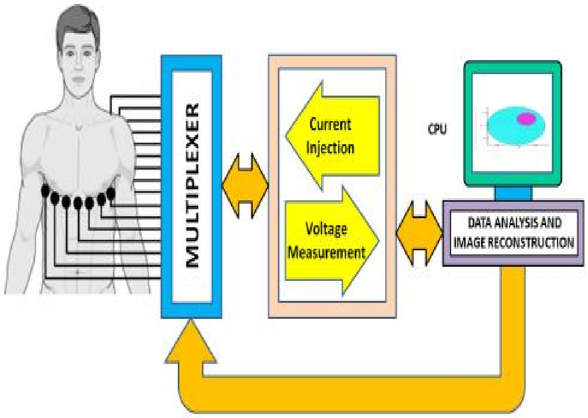


Figure 1. A medical EIT schematic: Electrode array attached to the patient's body

The area of interest from which image is constructed is shown in figure (1) in which electrodes are attached over the body surface and the current is injected and voltage across electrodes are measured and those values are taken into computer system to construct an image. We therefore expect that bio-impedance measurements will be tissue-type specific. Tissue and cells also exhibit electrically capacitive properties, and impedance measurements will therefore be frequency dependent.

3. Electrical equivalent circuit of biological cells.

EIT is a non-invasive technique to measure two or three-dimensional impedance for medical diagnosis involving several diseases. To measure the impedance values, electrodes are connected to the skin of the patient and an image of the conductivity or permittivity of living tissue is deduced from surface electrodes. The determination of local impedance parameters can be carried out using an equivalent circuit model. The electrical equivalent model is shown in figure (2) in which extra-cellular medium resistance is Re, intra-cellular medium resistance is Ri and cell membrane capacitance is Cm.

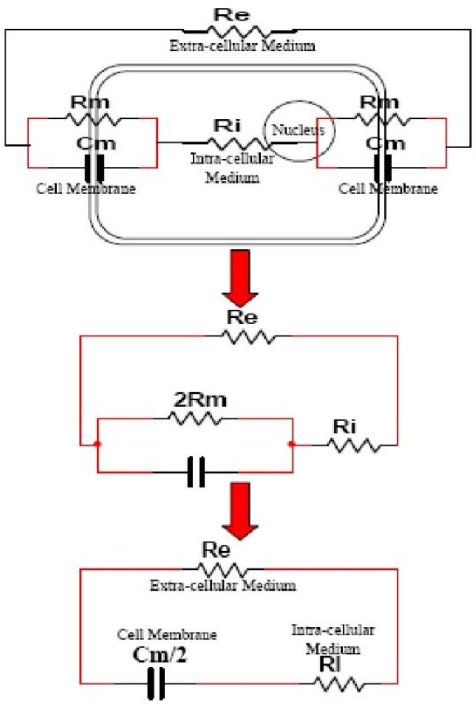


Fig 2. Electrical equivalent circuit of biological cells.

However, the estimation of inner tissue impedance distribution using impedance measurements on a global tissue from various directions is an **inverse** problem. Hence it is necessary to solve the inverse problem of calculating mathematical values for current and potential from conducting surfaces [6].

3. Block diagram of system

Consequently, the Fourier transform of V(t) will provide the voltage transform V(s). So, once the time domain voltage V(t) and current I(t) are acquired and are transformed to V(s) and I(s), the impedance spectroscopy Z(s) is recovered by (1).

$$Z(s) = \frac{V(s)}{I(s)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where Z(s) represents both magnitude and phase of impedance.

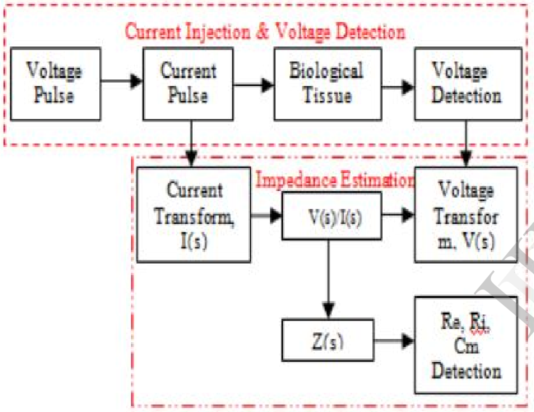


Fig 3. Block diagram of bio-impedance measurement system.

When a current pulse is injected, the voltage across the tissue would be V (t) = I (t)*h (t) where I(t)*h(t) represents the convolution sum of time domain current, I(t) and the impulse response of the bioelectrical equivalent circuit, h(t).Once impedance data is retrieved from frequency transform of voltage and current pulse, it is enough either to work with magnitude or phase to estimate Re, Ri and Cm, where successful estimation of impedance components Re, Ri and Cm from current and voltage pulse can be obtained. The transfer function of bioelectrical equivalent circuit of figure (2) and the change in pulse shape is shown in Fig. (4).

4. Pulse response of bioelectrical circuit.

Current source is the most important part of bioelectrical impedance measurement system and should have very good stability in providing current irrespective to the load variation and current value should be in 500 µA to 0.9 mA [1]. An EIT excitation source consists of the signal generator and the voltage-to-current converter. The frequency and the current stability of excitation source rely on the signal generator to a large extend. Direct digital synthesizers, DDS, are increasingly welcomed in modern communication systems and precise electronic systems, owing to their significant advantages over phase-locked loop synthesizers.

4.1 The Frequency adjustment

The choice of frequency is very important aspect in EIT as ac signal need to be applied to the body element of interest and the area over which electrodes are attached could have different electrical properties, so proper selection of frequency is important one .The two sine-waves with same in amplitudes and phase, but wide range of frequency demands a circuit which will provide the same. The changing the frequency controller can generate signal with different frequency and this is the very multi-frequency requirement an EIT measurement needs most.

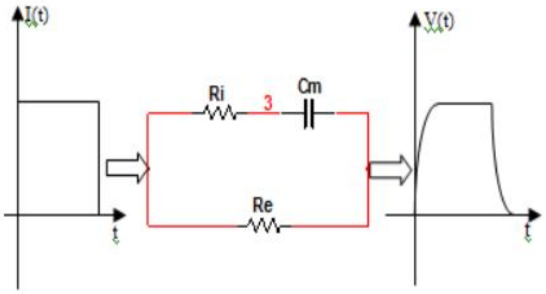


Fig 4. Pulse response of bioelectrical circuit.

4.2 Amplitude adjustment

The circuit needs to adjust the amplitude from the current source because human body has variety of cell and accordingly have different values of conductivity, so judicious selection of amplitude of current form source is necessary for EIT.

4.3. Phase adjustment

Two orthometric wave forms of sine and cosine with the same amplitude and frequency are important. Two mutually orthometric signals of sine-wave and cosine-wave can be used in quadrature demodulation to detect the real-part and imaginary part information in EIT measurement [4].

5. Consideration of electrodes

Electrical bioimpedance measurement sends a small AC current into the body by electrodes or electrode system. In the measurement, bioelectrical measurement electrodes, for instance, ECG, EEG, EMG, are used, but the effect is not good enough. Especially in the Electrical Impedance Tomography EIT , where electrode array consisting of ten or more electrodes are used [2]. The object of electrical bioimpedance measurement is the impedance or impedance changes of biologic tissue. The electrode used in electrical bioimpedance measurement can work under AC stimulation, the electrode impedances of both DC and AC, the stability of them are much important. AC and DC impedance properties of four kinds of one-off Ag/AgCl ECG electrodes produced by different manufactories [2].

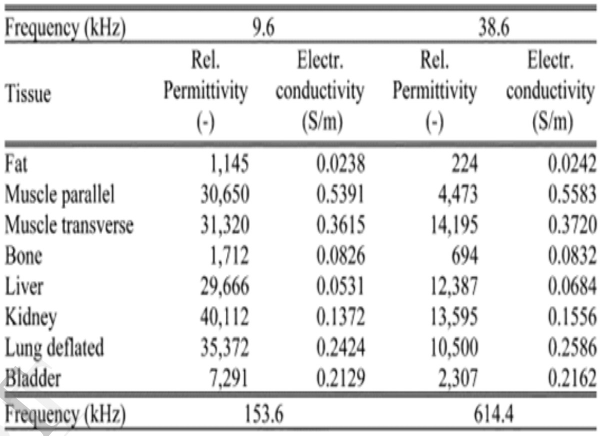
6. Impedance Estimation

Once the potential across bio-logical tissues is fetched, voltage spectrum is found using FFT in Matlab. By the same procedure current spectrum is also found from known pulse information and together with voltage and current spectrum, impedance spectroscopy is found by (1). At this final point, the magnitude of impedance spectrum data is calculated and fitted to find impedance parameters Ri and Cm applying least square method [1].

7. Electrical properties of biological tissues

Living tissue has complex structures for components and dimensions. Biological tissues have complex electrical impedance related to the tissue dimension, the internal structure and the arrangement of the constituent cells. Therefore, the electrical impedance can provide useful information based on heterogeneous tissue structures, physiological states and functions . In addition the concepts of time varying distribution of electrical properties inside a human body such as electrical conductivity and (or) permittivity can be used to analyze a variety of medical conditions. High conductivity materials allow the passage of both direct and alternating currents and high permittivity materials allow the passage of only alternating currents. Both of these properties are of interest in medical systems since different tissues have different conductivities and permittivities. The following table shows the electrical properties of tissues for human being [6].

Table II
Electrical properties of biological tissues



Frequency (kHz)	9.6		38.6	
Tissue	Rel. Permittivity (-)	Electr. conductivity (S/m)	Rel. Permittivity (-)	Electr. conductivity (S/m)
Fat	1,145	0.0238	224	0.0242
Muscle parallel	30,650	0.5391	4,473	0.5583
Muscle transverse	31,320	0.3615	14,195	0.3720
Bone	1,712	0.0826	694	0.0832
Liver	29,666	0.0531	12,387	0.0684
Kidney	40,112	0.1372	13,595	0.1556
Lung deflated	35,372	0.2424	10,500	0.2586
Bladder	7,291	0.2129	2,307	0.2162
Frequency (kHz)	153.6		614.4	

8. Conclusion

Electrical bioimpedance technology is a noninvasive measurement method. According to the electrical properties of body tissue or organs and their changes, the technology extracts biomedical information relative to physiology and pathology situation of human body. Usually, it applies a small alternative current or voltage to the measured object, through electrode system on the surface of body, measures relative impedance of the measured tissue or organs. This technology has advantages of noninvasive, inexpensive, safe, rich functional information, and easy to operate [2]. The accurate amplitude and phase information for image reconstruction is achieved. This design method is reliable and simple to provide technology support for complex impedance detection in EIT measurement [3].

9. References

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