Chapter 1
Prototype of a Low-Cost Impedance Tomography Based on the Open-Hardware Paradigm

David Edson Ribeiro
Universidade Federal de Pernambuco, Brazil

Valter Augusto de Freitas Barbosa
Universidade Federal de Pernambuco, Brazil

Clarisse Lins de Lima
Universidade Federal de Pernambuco, Brazil

Ricardo Emmanuel de Souza
Universidade Federal de Pernambuco, Brazil

Wellington Pinheiro dos Santos
https://orcid.org/0000-0003-2558-6602
Universidade Federal de Pernambuco, Brazil

ABSTRACT

Electrical Impedance Tomography (EIT) is a noninvasive, painless, and ionizing radiation-free technique for image acquisition of a region of interest. It is performed through electrical parameters. The method is based on the application of an alternating electric current pattern of low intensity through electrodes arranged around the surface region in order to obtain the image and also to measure the excitation electrical potentials. The aim of this study is to develop a device based in open hardware. Furthermore, the authors aim to build a prototype of a data acquisition system based on EIT. This device is the first step to obtain a complete and portable tomography equipment at a low cost.

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INTRODUCTION

Electrical Impedance Tomography (EIT) is a noninvasive and nonionizing technology for tomographic imaging. It is based on the application of a low amplitude, high frequency, alternating electric current pattern through electrodes (Tehrani, Jin, Mcewan & Schaik, 2010). These electrodes are arranged around the surface of the body section and the resulting potential in the electrodes is, then, measured. EIT images are the computational reconstruction of the estimated mapping of electrical conductivity or permittivity within the body section, calculated from the relationship between excitation data and response data. This imaging technique is starting to be used in the process of breast cancer diagnosis.

Breast cancer is the type of cancer that most affects women in the world (Walker & Kaczor, 2012;). The best strategy to fight this disease is still the early detection of the tumor. In other words, the best way to decrease the fatality rate associated to breast cancer is detecting it in early stages (Zou & Guo, 2003). As highlighted by Zou & Guo (2003), there is evidence that malignant tumors have lower electrical impedance value than neighboring tissues. Following from this premise, some studies have been pursued to evaluate if the EIT can be applied as a breast cancer detection method. Cherepenin et al. (2001) performed 3-D breast images to detect breast cancer through a planar array of electrodes arranged in a square shape. In 2002, he did the same procedure using a circular matrix (Cherepenin et al., 2002). Comparing his approaches, the circular matrix is more adequate rather than the square matrix because the electrodes on the square corners have low contact with the breast. This fact results in blurs on the reconstructed image corners, therefore, the central region of the image is the only region appropriate for analysis. The three-dimensional image of the breast is made from several images made in different slices at different distances from the electrode matrix (Cherepenin et al., 2001; Cherepenin et al., 2002). When applied to breast images, some authors also call the technique Electrical Impedance Mammography (EIM) (Trokhanova, Okhapkin, & Korjenevsky, 2008; Huber et al., 2010; Zhang, Wang, Sze, Barber, & Chatwin, 2014). Currently, the most widely accepted technique for early detection of breast cancer is mammography, which is a method that uses ionizing radiation and causes discomfort to the patient. So, in this case, EIT is a promising method, mostly because it is noninvasive and free of ionizing radiation.

In the medical field, EIT has several other applications, such as monitoring mechanical pulmonary ventilation in intensive care patients (Alves, Amato, Terra, Vargas, Caruso, 2014). In this case, the treatment efficiency is usually measured by blood tests. From samples taken throughout the day that evaluate the amount of oxygen and carbon dioxide present in the blood. With the use of EIT, it is possible to monitor the volume of injected air in real time. Furthermore, EIT can also be used to detect pulmonary embolism or blood clots in the lungs (Cheney, Isaacson, & Newell, 1999; Adler et al., 2009), to help in the prostate cancer detection (Wan et al., 2013), to monitor cardiac activity and blood flow in the heart (Eyuboglu, Brown, Barber & Seager, 1987). It can also be used to perform functional images of brain activity (Bayford, 2006) and to detect subdural hematomas (Dai et al., 2013). Besides the medical field, EIT also excels in geophysical and industrial applications. In geophysics, electrical impedance tomography is also known as electrical resistivity tomography (ERT) (Bouchette, Church, Mcfee, & Adler, 2014). Among its applications in geophysics, EIT can be used to find underground storage of minerals and different geological formations (Cheney, Isaacson, & Newell, 1999). It can help to detect buried objects and anti-tank mines in different soil types, especially for wet and submerged soils, where other mine detectors perform poorly (Church, Mcfee, Gagnon, & Wort, 2006; Bouchette et al., 2014). It can also be used to monitor in situ remediation processes for the removal of volatile organic compounds in groundwater or soil (Daily & Ramirez, 1995). In the industry field, EIT can be used to monitor biphasic or multiphase