Development of a Self-sufficient Ad Hoc Sensor to Perform Electrical Impedance Tomography Measurements from Within Imaged Space

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Abstract. Electrical Impedance Tomography (EIT) is an ill-posed problem whereby there are insufficient measured data to solve for a large amount of unknowns (finite elements). Conventionally, EIT measurements are performed on the boundary of an object or a process vessel. This results in a lower spatial resolution in central regions far off the conventional periphery electrodes. This paper presents the development of a self-sufficient EIT sensor with an aim to obtain EIT measurements from any locality within the object or the process vessel. An ad hoc EIT sensor that performs the current injection and voltage measurement around two pairs of electrodes is developed. The sensor consists of a current source, voltage amplifier, multiplexers, and microcontroller. Tests were conducted on a phantom tank. The sensor successfully performs localized voltage measurements from the interior of the imaged space with channel SNR average of 15dB.

Keywords: Electrical Impedance Tomography, Howland current source, EIT sensor.

1 Introduction

Electrical Impedance Tomography (EIT) is a simple solution to obtaining information about the interior of an object or a process through electrical excitation and measuring of voltage, whereby interior conductivity distribution within an object or a process vessel can be reconstructed in a form of tomograms. EIT has shown potential over existing imaging modalities [1], however, the main drawback has been its low spatial resolution towards the center of the imaged space. The favorable effort to solve this problem has been increasing the number of measurements by increasing the number of conventional electrodes available [2]. Various conventional electrode arrangements such as; ring, linear and matrix arrangements are explored in [3]. Multiple rings and semicircle have also been used [4]. One of the limitations of conventional arrangements is that the electrodes are usually located around the periphery of the object under test, hence limiting where the changes in conductivity in the medium can be detected and measured.

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Several studies [5-8] have investigated the feasibility of integrating internal electrodes to perform measurements from within the imaged space. Murphy et al [9] used electrodes mounted on a rotating impeller to further extend the number of measurements of a conventional EIT system. The electrodes mounted on the rotating impeller were only used as current sinks. Chin et al [10] employed voltage sensor nodes to acquire localized measurements within the imaged space. Each sensor node is equipped with two electrodes that only function to acquire voltage difference measurements, similar to those obtained using wall-mounted electrodes. The authors reported overall improvement of sensitivity across the medium, however, there was a lack of new information collected within the central regions. This is attributed to the fact that electric excitation is limited to wall-mounted electrodes while the internal electrodes acted only as a voltage measuring electrodes. Additionally, Zhang et al [11] used an array of long steel-cased boreholes as electrodes to detect oil-water distribution in oil fields. Bai et al [12] used borehole-to-surface as electrodes to detect ground anomalies. In both cases, the electrodes are fixed at one side of the imaged space, therefore, limiting detection of anomalies located far off the electrodes [13].

This paper presents the development of a self-sufficient ad hoc EIT sensor that is equipped with two pairs of electrodes which act as a current source and voltage measuring system. This allows for current injection (source and sink) and voltage measurements to be performed from any location within the imaged space. This paper consists of four sections. Section 2 describes the methods of developing a four-electrode self-sufficient EIT sensor. Section 3 presents simulation and experimental results for the current source and voltage measurements. The prototype is tested on a process vessel containing tap water with and without inserted anomaly. Conclusions are presented in Section 4.

2 Method

The sensor design modules include a current source, an analog switch and selection, a voltage sensor, and a microcontroller that handles analog-to-digital conversion and communication. The term ‘self-sufficient’ means the EIT sensor consists of its own current source and a voltage sensing circuit. This is to enable the EIT sensor to perform current injection and localized voltage measurement from “any” interior location using four electrodes attached around a small 3D structure made of non-conducting material. Fig. 1 presents the system architecture of the self-sufficient EIT sensor.