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Conference Paper · June 2021

DOI: 10.5281/zenodo.4635480

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Abstract: An extensive EIT hardware simulation approach, merging parametric EIT circuit setups and 3D thoracic tissue models is described. It can used as an effective tool for EIT-thoracic imaging applications prior to implementation.

1 Introduction

Evaluation of EIT hardware circuitry is usually performed over saline-content phantom tanks or resistor meshes. Furthermore, EIT hardware design and implementation process for specific medical applications, is commonly based on specifications defined by previous literature observations or electric field-nature simulations that do not include hardware. However, it is hard to simulate both EIT hardware and the Subject Under Test (SUT). We propose a fastiduous simulation approach combining EIT hardware configuration and thoracic SUT, in an effort to predict certain hardware configuration's performance in relative applications.

2 Methods

The proposed approach makes use of a database which includes the dielectric properties of numerous body tissues over a wide frequency span [1], as well as a recent update in EIDORS [2] which allows the transform of a F.E.M. structure to a N-electrode port RLC circuit.

A fine-meshed $3D$ thoracic F.E.M. structure is firstly created with the NETGEN tool, which can be based on CT images. Then a specific measuring frequency is selected and a Python script exctracts the present tissue's dielectric properties for this frequency, transfering them in MATLAB. The corresponding conductivity σ and permittivity ϵ values are then assigned to the F.E.M. structure, which is then transformed to a N-port RLC. This is merged with the EIT ciruitry in SPICE, where transient simulations take place. The outputs are written on a PWL file and sent to MATLAB for digital processing. The ADC, DAC and demodulation functionality is also simulated. Finally the EIDORS tool takes the demodulated data to produce the EIT images. The whole process is presented in Fig. 1.

It is important to note that following this approach, any hardware noise or error's effect in both the signal and the image can be directly observed by introducing it in the simulated hardware (e.g. white noise, electrode disconnections, VCCS missmatches, channel imbalances combined with low instrumentation CMRR, e.t.c.). Furthermore, the impact of alternative topologies or digital signal processing approaches on the image can also be simulated.

3 Results

Results for 2 selected configurations, for $I = 1.2mA_{p-p}$ when total white noise is $6mV_{p-p}$ are presented in Fig. 1. Direct G-N approach with NOSER prior has been used.

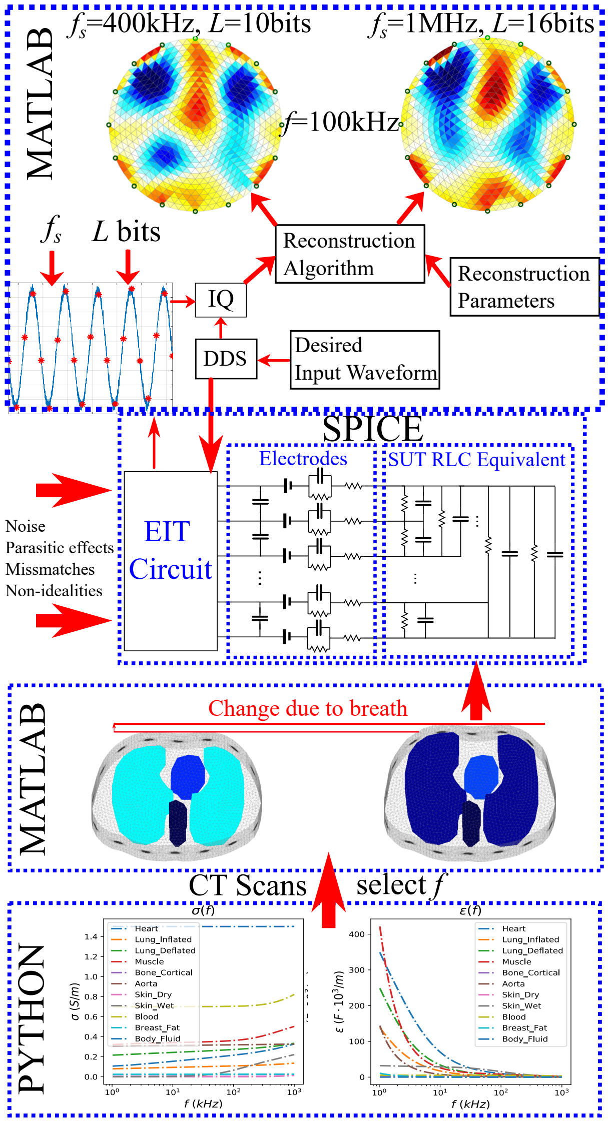

Figure 1: Brief schematic of the proposed simulation approach. Code and models are available online in Github

4 Conclusions

An extensive simulation approach which combines EIT hardware, the SUT, the digital signal processing and the reconstruction has been presented. An application in EIT lung imaging is demonstrated.

References

[1] S Gabriel, R Lau, C Gabriel. The dielectric properties of biological tissues: II. Meas. in the freq. range 10 Hz to 20 GHz. *Physics in medicine & biology* **1996** *41*, 11, 2251

[2] Boyle A, Adler A. Integrating Circuit Simulation with EIT FEM Models. *19th Int. Conf. of Biom. Applications of EIT* **2018**