ELECTRICAL IMPEDANCE TOMOGRAPHY SYSTEM DESIGN AND IMPLEMENTATION FOR BREAST CANCER DETECTION

By

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ABSTRACT

The Adaptive Current Tomograph, generation 4 (ACT4) is a high speed, high precision, multi-channel electrical impedance tomograph that is currently being used for breast cancer detection. It can support up to 72 channels, and operate at discrete frequencies in the range of $3.3\bar{3}$ kHz to 1 MHz. The instrument operates in voltage source mode, i.e. it can apply multiple voltages and measure the resulting currents. This thesis describes improvements made to ACT4's firmware design and the development of a real time system that can apply optimal current patterns.

The firmware changes outlined in this thesis include modifications made to the Field Programmable Gate Arrays (FPGA) inside ACT4. The signal generator, the sampling clock, the matched filter, the switch multiplexer and the analog to digital converter interface modules have been updated to operate the system at new frequencies, higher precision and higher speed. The current signal-to-noise ratio (ISNR) showed only a small improvement to about 16.5 bits of precision for frequencies up to 333.3 kHz and 14.5 bits at 1 MHz. However, the voltage signal-to-noise ratio (VSNR) showed a marked improvement to about 105 dB, i.e. an increase of at least 15 dB for all the frequencies. This VSNR corresponds to approximately 17.5 bits of precision.

Radiolucent electrode arrays are attached to ACT4 using shielded coaxial cables to collect EIT data in register with X-ray mammography data. These radiolucent electrode arrays have a complex layered structure that results in a large capacitance to ground and a small series resistance. Further, these shielded cables also introduce a small but significant series resistance and inductance and a small shunt capacitance to ground. There is also the issue of crosstalk between adjacent electrodes on the radiolucent array that needs to be minimized. Several compensation techniques and the corresponding results are presented in this thesis that result in an improvement in the measurement accuracy of the system.

An iterative current synthesizer algorithm is presented that can apply current patterns using the voltage sources in ACT4. Further, another algorithm is pre-

sented that can determine the optimal current patterns for the body under test. Application of these optimal current patterns is known to result in an increase in the distinguishability of the system. This algorithm identifies poorly contacting electrodes and computes optimal current patterns for the electrodes having good contact with the body under test. Poorly contacting electrodes are those electrodes that make improper contact with the body being studied and the inclusion of these electrodes in the measurements produces a corrupted data set.

Ultimately, a system that combines the current synthesizer algorithm, the optimal pattern generation algorithm and the array compensation techniques has been implemented in ACT4's user interface. This system uses voltage sources adaptively to apply optimal current patterns to the load having either good or bad contact with the electrode arrays. The implementation of the system and the corresponding results from several experimental studies are presented to demonstrate the overall functionality of the system.